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CIVIL ENGINEERING.

For the Journal of the Franklin Institute.

General Problem of Trussed Girders. By De Volson Wood, Prof. C.E., University of Michigan.

Concluded from page 317, vol. xlix.

In the latter part of the preceding article I found the position of the neutral axis when the resistances of the fibres are directly proportional to their distance from the neutral axis. We will now proceed to find it according to Barlow's theory.

b. Let there be two laws of resistance. According to one let the resistances vary directly as the distance from the neutral axis; and according to the other let the resistance be the same on each unit.

1. Let the moduli of elasticity be equal. Then will the resistances to *direct* elongation or compression be equal at equal distances from the neutral axis.

Using the notation before given, and we have $\frac{s}{d_t} = \frac{c}{d_c} = s =$ the resistance of a unit of fibres at a unit's distance from the neutral axis to *direct elongation or compression.* I speak of DIRECT resistances because the *longitudinal shearing* is not included.

Hence, $s\int_0^{d_t} zy\,dy =$ the *direct* resistance to tension,

$$s\int_o^{d_c} zy\,dy = \text{the } \textit{direct} \text{ resistance to compression,}$$

and since $\int_o^{d_t} z\,dy$ is the total area which is subjected to tension, we have

$$\varphi\int_o^{d_t} z\,dy = \text{the resistance to longitudinal shearing on the side of tension.}$$

$$\varphi\int_o^{d_c} z\,dy = \text{the resistance to longitudinal shearing on the compressed side.}$$

Hence the first of equation (61) becomes

$$s\int_o^{d_t} zy\,dy+\varphi\int_o^{d_t} z\,dy-s\int_o^{d_c} zy\,dy-\varphi\int_o^{d_c} z\,dy=0,$$

$$\text{or } s\int_{d_c}^{d_t} zy\,dy+\varphi\int_{d_c}^{d_t} z\,dy=0. \quad . \quad . \quad . \quad (99).$$

EXAMPLE.—Let the beam be rectangular; b the breadth, and d the depth.

Then we have

$$sb\int_{d-y}^{y} y\,dy+\varphi b\int_{d-y}^{y} dy=0,$$

$$\text{or } \tfrac{1}{2}s\left[y^2-(d-y)^2\right]+\varphi\left[y-(d-y)\right]=0,$$

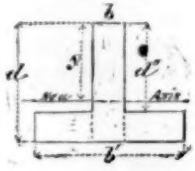
$$\therefore y=\tfrac{1}{2}d,$$

or the neutral axis coincides with the centre of the sections.

If the horizontal plane which is passed through the middle of the depth, divides the beam into two equal and symmetrical parts, then will the neutral axis lie in this plane, for the longitudinal shearing will be the same in the two parts, and hence the second term of (99) will be zero, and the equation reduces to equation (87), which shows that the neutral axis passes through the centre of the sections, which, in this case, is at half the depth. Hence the neutral axis passes through the centre of beams having circular, elliptical, or regular polyginal sections, double T or H sections with equal flanges, and tubular girders in which the hollow is similar to the full section. But it does not pass through the centre of triangular or single T beams, or other non-symmetrical forms.

EXAMPLE.—To further illustrate the use of equation (99), I will apply it to a single T, Fig. 35. Using the notation as given in the figure, and equation (99) will give for the part above the neutral axis

FIG 35



$$\tfrac{1}{2}s\,by^2+\varphi\,by \quad . \quad . \quad (100).$$

To find it for the lower part we suppose that the vertical web passes through the flanges to the bottom; hence we have for the lower part of the web,

$$\tfrac{1}{2}s\,b(d-y)^2+\varphi\,b(d-y) \quad . \quad . \quad (101).$$

According to the 4th principle, as stated in the preceding article, page 310, the longitudinal shearing stress in the flanges is $\frac{d'}{d-y}\varphi$. The width of both flanges is $b'-b$. Hence, for the sum of all the forces in the flanges we readily find

$$\tfrac{1}{2}s(b'-b)\left[(d-y)^2-(d''-y)^2\right]+\frac{d'}{d-y}\varphi\left[(d-y)-(d''-y)\right](b'-b),$$

$$\text{or } \tfrac{1}{2}s\,(b'-b)\,(d'd+d'd''-2d'y)+\varphi(b'-b)\frac{d''^2}{d-y} \quad . \quad . \quad (102).$$

Substitute (100), (101), and (102) in the first of (61), and it gives

$$\tfrac{1}{2}s\,by^2+\varphi\,by-\tfrac{1}{2}s\,b(d-y)^2-\varphi\,b(d-y)-\tfrac{1}{2}s\,(b'-b)(d'd+d'd''-2d'y)-\frac{\varphi(b'-b)d''^2}{d-y}=0,$$

from which y may be found.

2. Let the moduli of elasticity be unequal. In this case, the direct strain, $y\,s$, brings into play the elastic resistance; hence, for this strain we proceed as in the preceding theory; but the expression for the longitudinal shearing will be exactly of the same form as in the preceding case, or $\varphi\int_{d_c}^{d_t} z\,dy$.

3. *To find the position of the neutral axis so as to give a minimum strength.*

This is equivalent to making the second member of equation (84), or $\frac{s\,I}{d_1}+\varphi\iint y\,dy\,dx$, a minimum. As I have not succeeded in reducing this to a more definite form, dependent upon the form of section, I am obliged to reduce it for each special case. To show how to treat it, I will apply it to rectangular beams. As before, let b be the breadth, and d the depth, and $I=\iint y^2\,dy\,dx$. Then we have

$$s\int_o^b\int_{-(d-y)}^{y} y^2\,dy\,dx+\varphi\int_o^b\int_o^y y\,dy\,dx+\varphi\int_o^b\int_o^{d-y} y\,dy\,dx=\text{minimum.}$$

$$\text{Or, } \frac{b\,s}{3y}(d^3-3d^2y+3dy^2)+\frac{\varphi b}{2}\Big(y^2+(d-y)^2\Big)=\text{minimum}, \quad . \quad (103)$$

$$\therefore\ y^3+\frac{s-\varphi}{2\varphi}y^2=\frac{s}{6\varphi}d^3,$$

from which y may be found. If $\varphi = s$, as it does very nearly for cast iron beams having solid sections, we find

$$y = 0{\cdot}54958d, \text{ or } 0{\cdot}04958d$$

from the centre of the section. Comparing this result with that found under the former hypothesis, (see Example 1, which follows equation (94),) and we see that the neutral axis is nearer the centre of the beam at the instant of rupture, according to this hypothesis, than according to the former. If φ be zero, equation (103) will give the same result as (94). If φ be very large compared with s, or $s = 0$, equation (103) gives $y = \frac{1}{2}d$; hence, we infer *that all positive values of φ makes the neutral axis nearer the centre of the beam than if it were zero.* The same general principles are applicable to beams of any form.

B. *Suppose that the deflecting forces are inclined to the axis of the beam.*

a. Adopt the common theory, and let the moduli be unequal.

Let φ be the angle which the direction of force makes with the axis of the beam.

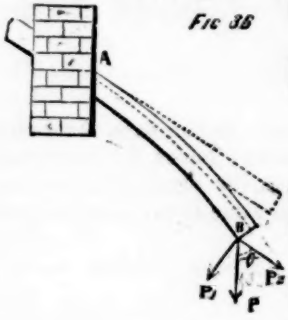


Fig 38

Then resolving the force normally and perpendicularly to the axis of the beam, and we have,

For the former, $P_1 = P \sin\theta$;

For the latter, $P_2 = P \cos\theta$.

The former tends directly to deflect the beam, while the latter tends, in this case, to elongate it.

Proceeding as in the preceding article, page 314, and we find,

For the total resisting forces to tension,

$$\frac{c\,E_t}{dx}\int\int_{o}^{d_t} y\,dy\,dx;$$

for the total resisting forces to compression,

$$\frac{c\,E}{dx}\int\int_{o}^{d_c} y\,dy\,dx,$$

and these in the first of (59) give,

$$\frac{c\,E_t}{dx}\int\int_{o}^{d_t} y\,dy\,dx-\frac{c\,E_c}{dx}\int\int_{o}^{d_c} y\,dy\,dx = P\cos\theta \quad . \quad (105).$$

The similarity of the triangles O L N and N e *k*, Fig. 31, and equation (89) give $c = \frac{d}{y} = \frac{dx}{\rho}$, which, in (105) gives

$$E_t \iint_0^{d_t} y\,dy\,dx - E_c \iint_0^{d_c} y\,dy\,dx = \rho P \cos\theta \quad . \quad (106).$$

The exact reduction of (106) is somewhat difficult, but as we have before observed E_t nearly equals E_c, and practically may be considered exactly equal, and as this hypothesis simplifies the equation, we

2. *Suppose that the moduli are equal.*

Then equation (106) becomes,

$$\iint_0^{d_t} y\,dy\,dx - \iint_0^{d_c} y\,dy\,dx = \frac{\rho}{E} P \cos\theta \quad . \quad (107).$$

Let K = the area of the section.

$\bar{Y}$ = the distance from the neutral axis (the origin of co-ordinates) to the centre of gravity of the sections.

Then, from mechanics we have

$$K\bar{Y} = \iint_{''}^{''} y\,dy\,dx = \iint_0^{d_t} y\,dy\,dx - \iint_0^{d_c} y\,dy\,dx\,;$$

hence, (107) becomes

$$\bar{Y} = \frac{\rho P}{E K} \cos\theta \quad . \quad . \quad . \quad (108).$$

Since ρ and θ are variable when the beam is curved, we see that the neutral axis is not parallel to the axis of the beam.

If $\theta = 90°$; $\bar{Y} = 0$.

If $\theta = 0$; ρ is infinite and $\bar{Y} = \infty$.

22°. *Let the direction of the force coincide with the axis of the bar.*

We shall then have $\beta = \gamma = 90°$; $\alpha = 0°$ or $180°$ according as the bar resists tension or compression; $b = c = 90°$, $a = 180°$ or $0°$ according as the force is tensive or compressive; and equations (4) and (5), vol. xlviii, page 231, gives

$$\Sigma F = \Sigma P.$$

The resistance ΣF may be expressed in terms of the elastic resistances, or the ultimate resistance. For the former we have the well known expression $\Sigma F = E K \frac{\lambda}{l}$; in which E is the modulus of elasticity, K the section, λ the elongation, and l the length. For the latter $\Sigma F = S K$ or $C K$, in which K is the transverse section, and S the modulus of strength, and C the modulus of resistance to crushing. We have thus come out at the equation which forms the starting point of most writers on the resistance of materials. My aim has not been to exhaust any part of the subject, but rather to show the *general* relation and dependence of the equations used in computing the strains on the several parts of a bridge, and the strains on the fibres of beams, by deducing all of them from the fundamental equations of statics.

In some cases I have reduced the equations so as to make them applicable to special cases, while in others they would require consid-

erable transformation. Of the former I might mention the parabolic arched truss; and of the latter, normally pressed arcs and some conditions for maximum shearing; but inasmuch as they are all statical problems, the equations which are applicable to them must be deducible from the equations which I have given. I might also have considered some problems in which we should determine the distribution of the parts so as to fulfil certain conditions which might be assigned to the strains. Such problems may properly form independent articles.

Some errors have crept into the work, most of which will be readily detected by the reader. I have noticed the following:

ERRATA.

Vol. xlviii, page 232, line 6, for $\Sigma P(\cos b - y \cos a)$ read $\Sigma P(x \cos b - y \cos a)$.
" " " line 14, for $\sin \beta$ read $\sin a$.
" " 309, line 11, for $V_0 \times {}_1\Sigma$ read $V - \Sigma_0 \times {}_1 - P$.
" " 378, line 18, for H D read $H_1 D$.
" " " bottom line, for P^X read P_X.
" " 379, line 5, for $\cos = \theta$, &c., read $\cos \theta =$.
" " 380, line 20, for Jone's read Jones'.
" " 381, line 12, for $\Sigma_0 \times \theta$ P read $\Sigma_0 \times P$.
" " 383, line 13, for $x = -\frac{w}{r}$ read $x = -\frac{wL}{r}$.

On the Size of Pins for connecting Flat Links in the Chains of Suspension Bridges. By Sir CHARLES FOX.

From the London Artizan, May, 1865.

In the construction of chains of this kind, it is of the highest importance that the pins which pass through and connect together the links of which the chains are composed should be of the right size, inasmuch as their being too small, as compared with the links through which they pass, renders ineffective a portion of the iron contained in the latter, which then exists only as a useless load to be carried by such links; while, at the same time, if the pins and heads of the links be too large, they become uselessly cumbersome and expensive.

Careful examination and experiments made upon a large scale (which will be explained hereafter) have brought out facts by which a simple rule has been arrived at—a rule that may safely be adopted as a guide in deciding upon the relative sizes of these two parts.

On this rule mainly depends the economical use of iron in the construction of such chains.

In this paper the term chains for suspension bridges implies such as are usually employed, and are composed of several flat bars of equal thickness throughout, placed side by side, but having their ends swelled edgeways, so as to form what are technically termed heads, and which are coupled together by pins passing through holes in such heads, as shown in Figs. 5 and 6 of the accompanying drawing.

In deciding upon the size of the pins it has often been assumed as a close approximation, that, as about the same force is required for

shearing as for breaking wrought iron by extension, it would be necessary to give the pin a cross section equal to the sectional area of the smallest portion of the link only. The fact of the possibility of links being torn and destroyed by the pin being too small to present the necessary bearing surface, althougth quite large enough to resist the calculated shearing force brought to bear upon it by the links, seems hitherto not to have attracted notice; but as the strength of a chain depends upon the proper extent of surface being offered by the pins of the links to pull against, such a mode as the one described has been proved by experiment to be altogether fallacious. For by this mode

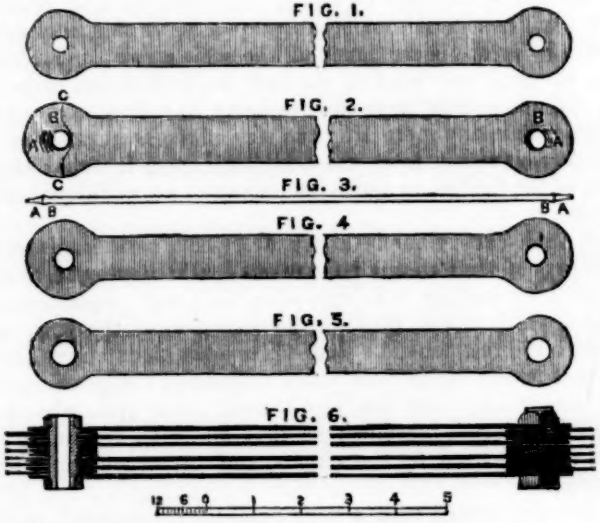


Fig. 1. Link for Kieff Bridge. Depth of head, 16½ inches, of centre, 10¼ inches, diameter of hole, 4½ inches.

Fig. 2. Elevation, showing result of proof.

Fig. 3. Section through centre, showing result of proof.

Fig. 4. Experimental link, with wider head. Depth of head, 18½ inches, diameter of hole, 4½ inches.

Fig. 5. Link with properly proportioned hole for pin. Depth of head, 17½ inches, diameter of hole, 6½ inches.

Fig. 6. Plan of chain and section of pin and links.

of estimating, the size of a pin passing through links 10 inches wide and of uniform thickness (that is, not having the head thicker than the body of the link) would be something less than 3½ inches in diameter, whereas (as will presently be shown) in order to get the whole benefit from such a link, the pin must be somewhat more in diameter than 6 inches, and for the following reasons:

In wrought iron the initial forces necessary to extend or diminish by compression the length of a bar are practically the same; and hence it arises that unless the surface of the pin on which the semi-cylindrical surface of the hole in the link bears is as great as the smallest cross section of the link itself, the head will be torn by the pin; and since

to provide this necessary surface it is essential to have a pin of much larger size, the question of its ability to resist the operation of shearing never arises, and the whole subject resolves itself into one of bearing surface.

If the pin be too small, the first result on the application of a heavy pull on the chain will be to alter the position of the hole through which it passes, and also to change it from a circular into a pear-shaped form, (*vide* Fig. 2,) in which operation the portions (A A, Figs. 2 and 3) of the metal in the bearing upon the pin become thickened in the effort to increase its bearing surface to the extent required. But while this is going on, the metal around the other portions (B B, Figs. 2 and 3) of the hole will be thinned by being stretched, until at last, unable to bear the undue strains thus brought upon it, its thin edge begins to tear, and will, by the continuance of the same strain, undoubtedly go on to do so until the head of the link be broken (or, rather, torn) through, no matter how large the head may be; for it has been proved by experiment that by increasing the size of the head, without adding to its thickness (which, from the additional room it would occupy in the width of the bridge, is quite inadmissible) no additional strength is obtained.

Acting upon the principle above described, most engineers have made the pins of their chains far too small, whereby much money has been wasted by making the links of a size, and consequently of a strength, of which it was, through the smallness of the pins, impossible to obtain the full benefit. Indeed, to such an extent has this been carried, that in one of the most noted suspension bridges hitherto constructed, a very large sum has been thrown away upon what is worse than wasted material, inasmuch as that material, remaining as load only, has to be carried by the chains, and correspondingly weakens the structure.

I am also acquainted with a very recently constructed suspension bridge, in which some of the links, which are 10 inches wide, have the holes in their heads but 2 inches, instead of 6½ inches, in which case more than two-thirds of the iron in the links is useless.

The first time my attention was seriously called to this important subject was when Mr. Vignoles entrusted my late firm of Fox, Henderson & Co. with the manufacture of the chains of the great suspension bridge for carrying a military road over the Dnieper at Kieff, which was constructed by him for the Russian government.

As the chains for this bridge weighed upwards of 1600 tons, upon which the expense of transport was very heavy, they having to be shipped to Odessa, and thence carted over very bad roads for upwards of 300 miles to Kieff, it was considered of the first importance to ascertain whether or not they were well proportioned; and accordingly a proving machine was specially prepared, of power sufficient to pull into two any link intended to be used on this bridge.

These links, as shown in the drawing attached to the contract, (see Fig. 1,) were, for convenience of transit, but 12 feet long from centre to centre of pin-holes, 10¼ inches wide by 1 inch thick in their body

or smallest part, with a head at each end also 1 inch thick, swelled out to 16½ inches in width, so as to allow of holes for receiving pins 4½ inches in diameter. The cross sectional area of these pins was 15·9 inches, or rather more than 50 per cent. in excess of the cross sectional area of the link at its smallest part.

According to the usual mode of ascertaining the size of these pins, by making them of such dimensions as to resist the force required to shear them, they possessed upwards of a third more section than was thus shown to be necessary. Still, in practice, a pin of this size proved altogether disproportionate to the size of the links, and required to be increased from 4½ to 6½ inches in diameter before it was possible to break a link in its body or narrowest part—fracture in every previous case taking place at the hole, and through the widest part of the head, as shown in Fig. 2.

The iron in the links for this bridge was of a very high quality, and was manufactured by Messrs. Thorneycroft & Co. from a mixture of Indian and other approved pig iron, and required a tensile strength of about 27 tons per sectional inch to break it, so that taking the narrowest part at, say 10 inches, a strain of 270 tons ought (had the size of the pin been in proper proportion) to have been required to pull it into two; instead of which, so long as the pins were but 4½ inches in diameter, the head tore across (as shown at Fig. 2) at its widest part with about 180 tons, or two-thirds only of the strain desired and provided for, as far as the size of the body of the links was concerned.

This unexpected result led to the belief that the size of the heads was insufficient, and accordingly a few experimental links were prepared with their heads 2 inches wider than before (as shown in Fig. 4); but these nevertheless were found to require no additional force to tear asunder; hence it became obvious that fracture arose from some cause not yet ascertained.

As has already been stated, the rupture took place across the widest part of the head (c c, Fig. 2); but on attempting to adjust the piece broken off, to the position it originally occupied in the link, it was observed that while the fractured surfaces came in contact at the outside of the head, they were a considerable distance apart at the edge of the pin-hole. (See Fig. 2.)

This at once proved that during the application of the tension, which at last ended in producing fracture, the various portions of the head had been subject to very unequal strains; and upon careful examination, the rationale of this fracture became apparent from the consideration that the hole which originally was round had become pear-shaped, (see Fig. 2,) having altered its position, and that the iron of the link which, during the application of the load, bore upon the pin, and was consequently in a state of compression, had become considerably thickened in consequence, as was now evident, of an effort to obtain a greater bearing surface, (see A, Figs. 2 and 3,) while the other portion of the iron around the pin-hole, being subject to tension, had been so weakened and thinned by being stretched, as to cause a tearing action to take place, which, having once commenced, would obvi-

ously, by the continuance of the same strain, rend through the entire head, no matter what its width might be.

From this it was clear that any increase of size of the head (unless by thickening, which, as I have before stated, is inadmissible) was of no avail; and it was now that the principle which forms the subject of this paper became manifest, viz: that there was a certain area of semi-cylindrical surface of the hole having a bearing on the pin proportionate to the transverse section of the body or narrowest part of a link, and quite essential to its having equal strength in all its parts; and that any departure from this proportion could not fail to bring about either waste of iron in the body of the links, if the pin was of insufficient size to offer bearing surface, or waste of metal in the heads of the links and in the pins, if the latter were larger than necessary for obtaining this fixed proportion of areas.

Having arrived at this point, a link, similar in all respects to the previous one, with holes $4\frac{1}{2}$ inches in diameter, and which broke across the head with 180 tons, was taken, and its holes enlarged to 6 inches, but without increasing the width of the head, which still remained $16\frac{1}{2}$ inches; so that the only difference was the removal of an annular piece $\frac{3}{4}$-inch in width from the hole, and so making it 6 inches instead of $4\frac{1}{2}$ inches in diameter, thereby actually diminishing the quantity of iron in the head to this extent—when it was most interesting to discover that by this slight alteration, by which the semi-cylindrical surface bearing on the pin had been increased from 7·0 to 9·4 sectional inches, the power of the link to resist tension had increased in about the like proportion, having rendered a force of nearly 240 tons necessary to produce fracture.

From subsequent experience, it has become evident that had the pins of these chains increased to $6\frac{1}{2}$ inches diameters, giving a bearing surface of 10·2 square inches, the proper proportion between them and the body of the links would have been very nearly arrived at, while with those of only 6 inches in diameter about an inch of the body of the links was wasted.

The practical result arrived at by the many experiments made on this very interesting subject, is simply that, with a view to obtaining the full efficiency of a link, the area of its semi-cylindrical surface bearing on the pin must be a little more than equal to the smallest transverse sectional area of its body; and as this cannot, for the reasons stated, be obtained by increased thickness of the head, it can only be secured by giving sufficient diameter to the pins.

That as the rule for arriving at the proper size of a pin proportionate to the body of a link may be as simple and easy to remember as possible, and bearing in mind that from circumstances connected with its manufacture the iron in the head of a link is perhaps never quite so well able to bear strain as that in the body, I think it desirable to have the size of the hole a little in excess; and accordingly for a 10-inch link I would make the pin $6\frac{2}{3}$ inches in diameter, instead of $6\frac{1}{2}$ inches, that dimension being exactly two-thirds the width of the body, which proportion may be taken to apply to every case.

As the strain upon the iron in the heads of a link is less direct than in its body, I think it right to have the sum of the widths of the iron on the two sides of the hole 10 per cent. greater than that of the body itself. (See Fig. 5.)

As the pins, if solid, would be of a much larger section than is necessary to resist the effect of shearing, there would accrue some convenience, and a considerable saving in weight would be effected, by having them made hollow and of steel.

In conclusion, I would remark that my object in writing this paper has been, first, to call attention to the fact that a link is far more likely to be torn by the pin being too small, than a pin to be sheared by a link; and secondly, to try to establish a simple rule by which their proper comparative sizes may always be arrived at; and I have been induced to investigate this very important subject from having generally found in existing suspension bridge chains a wide departure from what is right in this respect, in having the pins far too small.

On the Wear and Tear of Steam Boilers. By Frederick Arthur Paget, Esq., C.E.

From the Journal of the Society of Arts, No. 649.

According to the published report of the engineer of the Manchester Boiler Assurance Company, forty-three explosions, attended with a loss of seventy-four lives, occurred in 1864 in this country. The engineer of the Midland Boiler Assurance Company gives the number as forty-eight, causing the deaths of seventy-five and the injury of one hundred and twenty persons. These statistics are confessedly incomplete, being, from obvious causes, numerically understated. The Royal Commissioners on the metallic mines report, that in the districts of Cornwall and Devon, boiler explosions are of very frequent occurrence;* and, in these sparsely populated districts, they easily escape the public attention. Explosions, again, which only injure without killing outright, and therefore do not call for a a coroner's inquest, also happen without attracting much notice. The figures cited thus understate the destruction and injury to life through boiler explosions, while only a guess can be hazarded as to the annual loss of property they cause. Each explosion testifies to the probability that a number of boilers have been prevented from exploding by mere chance, as also to much unchecked decay and deterioration, which might have been prevented by greater care and more knowledge. Besides, apart from the disastrous results of an explosion itself, the undue wear and tear of boilers means the suspension of the workshop or factory and the demurrage of the steam vessel. With respect to the causes of explosions themselves, "there are," to use the words of the late Mr. Robert Stephenson,† "but few cases which do not exhibit undue weakness in some part of the boiler;" and

* Report of the Commissioners on the Metallic Mines. Presented to both houses of Parliament by command of Her Majesty, 1864, page 21.

† Proceedings of the Institution of Civil Engineers, 1856, page 281.

the same opinion appears to be held by Prof. Faraday.* The opinion that an explosion is rather due to the weakness of the boiler than to the strength of the steam may, in fact, be said to be universal. There is, indeed, a very complex train of mechanical, chemical, and physico-chemical forces, leading to the deterioration and consequent destruction of a steam boiler, and it is probable that no other metallic structure is subjected to such complicated conditions. The pressure of the steam and the heat of the fire produce mechanical effects, while both the burning fuel and the water react chemically on the plates and in accordance with their varying chemical properties. Each of these agents play, so to speak, into the other's hands, furthering and quickening the other's progress. It is difficult to distinguish with strictness between the effects of each; and it is mainly for the sake of convenient examination that they be classified into—1. The effects of the pressure of the steam; 2. the mechanical effects of the heat; 3. the chemical effects of the fuel; 4. the chemical effects of the feed-water.

The Direct Effects of the Pressure of the Steam.

In calculating the working strength of a cylindrical boiler, the plates are assumed to be under a static load, and to be submitted to a tensile strain. The former of these assumptions is seldom, and the second is never correct. There are two principal causes that tend to exert impulsive strains on the sides of a boiler: 1. The sudden checking of the current of steam on its way from the boiler to the cylinder; 2. quick firing, attended with too small a steam room; and both may sometimes be found to act in combination. To the first of these causes the explosion, for instance, of one of the boilers of the *Parana* steamer, at Southampton, a few years ago, has been ascribed by the Government engineer surveyor;† to the second, the explosion of the copper boiler of the *Comte d'Eu* yacht, in France. According to Dr. Joule, the mere dead pressure of an elastic fluid is due to the impact of its innumerable atoms on the sides of the confining vessel. When the motion of a current of steam is suddenly checked, as by the valve, in its passage from the boiler to the cylinder, its speed and weight cause a recoil on the sides of the boiler analogous to the effects of the, in this case, almost inelastic current of water in the hydraulic ram;‡ this action is necessarily most felt with engines in which the steam is let on suddenly, as in the Cornish, and other single-acting engines, working with steam valves, suddenly affording a wide outlet, and as suddenly closing. It produces such phenomena as the springing or breathing of cylinder covers, and the sudden oscillations of gauges, noticed long ago by Mr. Josiah Parkes and others.§ Some years ago while standing on a boiler working a single-acting engine, and with a deficient amount of steam room, the writer noticed the boiler to slightly breathe

* Proceedings of the Institution of Civil Engineers, 1852, page 392.

† Rudimentary treatise on Marine Engines and Steam Vessels, etc. By Robert Murray, C.E., Engineer Surveyor to the Honorable Board of Trade, pages 74–78.

‡ Instituto di Scienze. Milano, 1829.

§ Transactions of the Institution of Civil Engineers. Vol. iii.

with every pulsation of the engine. The same action has been observed by others with boilers, the steam room of which is out of proportion to their heating surface. The intensity of the instantaneous impulses thus generated would be, as Mr. Parkes observes, difficult to measure, but their repeated action must readily affect the boiler at its mechanically weakest points. The more or less sudden closing of a safety-valve while the steam is blowing off would evidently produce the same effect; and this view is strengthened by the fact that the great majority of locomotive boilers—in which while at work there is no such sudden call on the reservoir of steam as in the Cornish engine—explode while standing with steam up at the stations.* It is not denied that, in the case of a locomotive, the mere extra accumulation of steam from the safety-valves being screwed down above the working pressure will also come into play. But there can be little doubt that most boilers are subjected, sooner or later, and with more or less frequency, to an impulsive load. This being the case, this consideration alone would demand a factor of safety of *six* in the designing of steam boilers. The Commissioners on the application of iron to railway structures, in their third conclusion on a mass of evidence which has made their investigations the most valuable ever conducted on the strength of materials, say, "that, as it has been shown, that to resist the effects of reiterated flexure, iron should scarcely be allowed to suffer a deflection equal to one-third of its ultimate deflection, and since the deflection produced by a given load is increased by the effects of percussion, it is advisable that the greatest load in railway bridges shall in no case exceed one-sixth of the weight which would break the beam when laid on at rest in the centre."†

Emerson showed, more than sixty years ago, that the stress tending to split in two an internally *perfectly* cylindrical pipe, submitted to the pressure of a fluid from the interior, is as the diameter of the pipe and the fluid pressure. He also showed "that the stress arising from any pressure, upon any part, to split it longitudinally, transversely, or in any direction, is equal to the pressure upon a plane drawn perpendicular to the line of direction." As in a boiler the thickness of the metal is small compared with the radius, the circumferential tension has been assumed to be uniformly distributed; and the strain per unit of length upon the transverse circular joint being only half that upon the longitudinal joints, the strength of the latter has been taken as the basis of the calculations for the tensile strength of the joints. But in taking the internal diameter of the boiler as the point of departure, the internal section has been assumed to be a correct circle, which would only be practically true in the case of a cylinder bored out in a lathe, and never in that of a boiler. Two of Emerson's corollaries from

* Reports of the Inspecting Officers of the Board of Trade, 1850–64. (The four locomotive boilers which burst last year all did so while standing. Neither the primary rupture leading to the explosions, nor the secondary rupture caused by the explosion, took place through the rivet holes.)

† Report of the Commissioners appointed to inquire into the Application of Iron to Railway structures. xviii.

his first proposition have, in fact, been neglected. He shows that if one of the diameters be greater than another, there will then be a greater pressure in a direction at right angles to the larger diameter, the greatest pressure tending to drive out the narrower sides till a mathematically true circle is formed. The second is that "if an elastic compressed fluid be enclosed in a vessel, flexible, and capable of being distended every way, it will form itself into a sphere."* A number of proofs can be adduced that both these influences are more or less at the bottom of the wear and tear caused by the direct action of the steam.

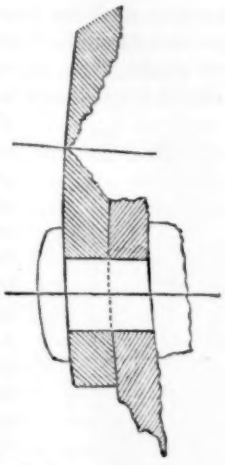
From 1850 to 1864 forty locomotive explosions, causing a loss of human life, have occurred in the United Kingdom. The Board of Trade reports in the Blue-books presented to Parliament, and more especially those by Captain Tyler, R.E., probably form the most valuable and connected series of records extant on boiler explosions. This is more especially the case with regard to wear and tear caused by the direct action of steam unmasked by the effects of the fire, as the barrel and outside fire-box of a locomotive cannot be said to be under the direct action of the heat. Perhaps the vibration of the boiler through the motion on the line may intensify this action, but it is clear that vibration cannot be a primary cause. The majority of the reports are illustrated by careful drawings. Eighteen of the forty boilers gave way at the fire-box—eleven from the crown of the inside fire-box being blown down upon the tube plates; seven from the shells or sides giving way. Twenty burst at the barrel; and two explosions may be ascribed to miscellaneous causes, from an originally defective plate, and from running off the line. Leaving out all those which occurred at the fire-box, as the majority of these might be ascribed to other influences than direct pressure, all the twenty explosions of the barrel could be traced either to internal furrows or to cracks, both running parallel with one of the longitudinal joints of one of the rings forming the barrel. All the joints which thus gave way were lap-joints; and the furrows or the cracks (and the former greatly preponderate in number) occur at the edge of the inside overlap, and, therefore, just at the point where the diminution of diameter caused by the lap-joint would be most affected by the pressure of the steam. (See Fig. 1.)

The plate at the channels shows distinct traces of lamination through the cross bending, and it is probable that plate of a good material will

* The action of a fluid pressing with equal forces in all directions can be evidently represented as to force and direction by innumerable radii of equal length led from a single point in all directions. Upon this principle may be explained the spherical shapes of soap bubbles, of the bulbs of thermometers, (blown while the glass was in a plastic state,) of the thin india rubber balls, used as playthings, and which are formed by forcing air into india rubber tubes closed at one end. Gas and air bubbles in water are necessarily flattened by the hydrostatic pressure. It is upon that principle that a gun of soft ductile iron often bulges out at the breech.

gradually laminate, while inferior metal will crack through in much less time. Nor are these furrows found with only lap-joints. Butt-joints, with a strip inside the boiler, and thus destroying the equilibrium of internal pressure, have been found to be attended with similar furrows. Channels of exactly the same character have been observed in locomotive boilers with lap-joints, which have exploded in Germany.*

Fig. 1.



(Half size cross section of the furrowed longitudinal joint in the fire box ring of a boiler which exploded at Overton station, on the 30th May, 1864. It does not differ from other furrows.)

Similar furrows, again, have been noticed in marine boilers, and in old boilers generally, longitudinal furrows being of course about twice as dangerous as those appearing transversely. The smoke-box tube-plates of inside cylinder-locomotive engines have been found to be similarly influenced by the racking action of the engines, showing furrows around the cylinder flanges. A parallel case is often found in Lancashire with the end-plates of double-flued Fairbairn boilers, which may have been too stiffly stayed to the barrel. Circular furrows, caused by the confined motion of the end-plates, are sometimes found at the base of the angle iron rings jointing the internal flues to the end-plates. But furrowing seems with no kind of boiler to be more felt than with locomotive boilers. This is due to the high pressure, to the thicker plates causing a coarser lap, and more especially to the fact that the unstayed barrel cannot be thoroughly examined without drawing the tubes, thereby enabling the furrow to enlarge itself unnoticed.

The inside fibres of a plate bent up while cold are necessarily initially in a state of compression. When the pressure from the inside comes on, striving to form a perfect cylinder, the plate gets bent to and fro by its own elasticity on one side, and by the pressure on the other. If the iron be brittle, it may crack right through ; if ductile, the outside fibres gradually lose their elasticity, and, necessarily aided by other causes, crack away. This action is progressive, and probably very rapid towards its later stages. Once a weak place formed itself it would have to do more and more of the work. Even when pulled by the direct tension of the testing machine, a lap-joint behaves in a somewhat similar way. For instance, a half-inch lap, solidly welded by Bertram's process, has only half the strength of the solid plate;† while the $\frac{3}{8}$-inch lap-weld has actually two-thirds of the strength of the entire plate.

Messieurs Jean Piedbœuf and Cie, of Aix-la-Chapelle, Düsseldorf, and Liege, who turn out annually upwards of one thousand steam

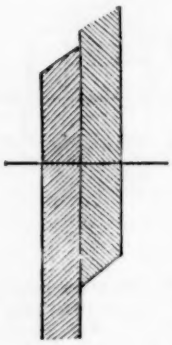
* Organ fuer die Fortschritte des Eisenbahnwesens. 1864, page 159.

† "Recent Practice on the Locomotive Engine," page 5.

boilers, use a lap-joint which probably gives slightly better results as to furrowing, while it is much easier to caulk, and must be therefore less injured by that process. (See Fig. 2.)

There is, however, another important appearance to be noted with respect to these furrows. An iron cylindrical vessel under internal pressure would, of course, rupture long before it could assume a spherical shape, from its ranges of elasticity and of ductility being so short. But it may be said to be undergoing three distinct stresses in as many directions. There is a stress acting on the ends, and tending to rupture the boiler in two halves in a direction parallel to the axis; there is the stress which is hoop tension in a true circle, but which acts with a cross bending strain in an ordinary boiler; and there is the stress which tends to make it assume the shape of a barrel, or to bulge it out in the centre of its length. The precise action on a material of several strains like this is a portion of the strength of materials which is still completely unknown. Its probable effects might be illustrated by the ease with which a stretched india rubber ring is cut through with a knife, or that with which a column under compression is broken by a blow from a hammer, or by the similar ease with which a tube under tension is split by a sharp blow; in fact, the operation of caulking a defective boiler under steam seems thus to often give it the finishing stroke which causes an explosion. The new boiler which burst from a defective plate at the Atlas Works, Manchester, in 1858, and that which burst through a crack at a longitudinal joint last January, at Peterborough, both gave way whilst being caulked. This again accounts for the fact that adjacent boilers sometimes explode one after the other, pointing at the same time to the danger into which a sound boiler may be thrown by an explosion.

FIG. 2.



(The edges of the plates are cut to an angle of 65° by means of inclined shears.)

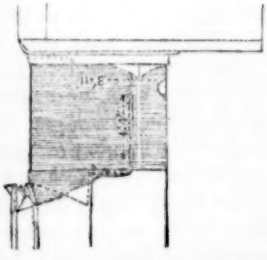
Upon the same principle it is probable that the modern guns, built up from strained rings, will be easily put *hors de combat* by shot. The probability is that a number of simultaneous strains in different directions diminish the elasticity of the material that would allow it to yield in any given direction. However this may be, it will be seen that it is only the pressure on the ends of the boiler acting parallel to the axis and tending to tear the cylinder through transversely, which bears fairly on the rivetted joint, or rather on that metal between the rivets which is left after punching. Unless the cylinder be perfectly correct inside, the circumferential strain resolves itself into cross bending, shifting the dangerous strain from the iron left after punching to the metal at the overlap. With respect to the stress tending to bulge the cylinder in the centre, it is clear that if we suppose a strip cut out from the entire length of the boiler, each portion of the length of this strip could be regarded as a beam under a uniformly distributed load.

As, however, with the lap-joint there is a double thickness of metal transversely, that joint is the strongest and stiffest portion to resist the stresses tending to bulge out the cylinder in the middle, and also to tear it into two halves. This affords some justification for the belief of old boiler makers, before rivetted joints were tried under a direct tensional load, that the joints are the strongest part of the boiler. And, indeed, this is what we find in practice. The thinest portion of the longitudinal furrows is generally exactly in the middle of the plate, and this is caused by the longitudinal stress, which is acting at right angles to the transverse cross bending stress. A strip cut from joint to joint is, in one respect, in the condition of a beam supported at both ends, uniformly loaded throughout its length, and, according to known principles, therefore giving way in the middle. (See Fig. 3.)

The middle ring of the boiler which burst on the Metropolitan Railway last year, and the fragments of which were examined by the writer, also first given way at a furrow. Captain Tyler reports that at from 16¾ to 19 inches from the transverse joint, or just about the middle of the plate, there was "very little metal left holding," while it gradually got to its original thickness of ⅜, as the groove receded from the centre of the plate and towards the transverse joints at each side.

It is impossible to deny the existence of an infinite number of stresses acting on the sides of a vessel undergoing fluid pressure, producing what, for want of a better term, might be called a "bulging strain." Instances of this action may be noticed in the sketch of the leaden pipes given by Mr. Fairbairn,* which were bulged out in the middle by internal pressure, as also in the fire-box sides† influenced by the same means, and in the centre of the surface. Unaccountably enough, the effect of such a strain on the ultimate resistance, and, above all, the elasticity of materials, has been entirely neglected by investigators, and there are no published data on the matter. The effect of the internal pressure is evidently resisted by a double thickness of plate at the joints, so that the load on the middle of a single ring may be considered as determining the weakest part of the boiler. One of the rings of the Great Northern boiler which exploded on the Metropolitan Railway last May had a length transversely of about (say) 36 inches from lap to lap, with an inside diameter of 45 inches. If we now suppose a strip one inch broad cut from the 36-inch long plate, parallel to the longitudinal axis of the boiler, this strip is, supposing there be a pressure of 100 lbs. to the square inch, uniformly loaded with 3600 lbs., equal to a transverse load of 1800 lbs. at the

FIG. 3.



(From Captain Tyler's report, dated 30th June, 1864, on the boiler explosion at the Overton station of the London & North Western Railway. The plate torn off is shaded, the course of fracture on the other side of the boiler is dotted, while the furrow is shown by the thick horizontal line.)

* "Philosophical Transactions, 1858," page 402.

† "Useful Information for Engineers, 1856." Appendix, xviii.

centre. Supposing the plate to form a true circle, a hoop one inch wide of the $\frac{3}{8}$ plate would be subjected, circumferentially, to a tensile load of 6000 lbs. per square inch, while (leaving out the diminution of the area at the ends through the flue tubes) each portion of the circle about 1 inch broad and $\frac{3}{8}$-inch thick, is subjected to a load of about 1125 lbs. acting parallel to the axis of the boiler.

To construct a general rule or formula that would take into account the distorting effects of the lap or of the welt of butt-joints would be impracticable; but it is clear that the usual mode of calculating the strength of a cylindrical boiler from the tensile strength of joints tested by weights, or hydraulic pressure, directly applied, is far from being correct. It is only tolerably correct with scarf welded joints, or with butt-joints with outside welts. Even here, the hoop tension of the true cylinder is resolved into a cross bending strain, if the cylinder does not form a correct circle internally. The usual formula would be practically correct, if the boiler were prevented from altering its shape during the impulses sometimes given by the steam, and the quieter buckling action caused by the alternate increase and fall of the pressure. In fact, a boiler, like a girder, does not merely demand a high ultimate strength, but also a stiffness which is the protection against alternative strains—against buckling or collapse.

Disregarding the effects of the thickness of the material, a perfect cylinder should theoretically afford the same ultimate resistance, whether exposed to external or internal pressure. Its resistance to collapse should indeed be greater, as most materials give more resistance to compression than to tension. This is not the case, as the distortion of form progressively weakens an internal flue, by increasing the load on its surface, while the contrary is rather the case with the boiler exposed to internal tension. Before Mr. Fairbairn showed the inherent weakness of flue tubes, their frequent explosions through collapse were ascribed to spheroidal ebullition and other similar causes. They are now, according to the engineer of the Manchester Boiler Association, stronger than the shells, by means of the T-iron and angle iron bands now generally used, and also by the excellent seams introduced by Mr. Adamson so long ago as 1852.* While T-iron and other bands could be used for the barrels of boilers not exposed to the fire, (as is recommended in France† and by the Board of Trade Inspector of Railways,) Adamson's seams reversed would probably form excellent transverse joints for a shell fired from the outside, and, with a boiler like this, thin and narrow plates could be used, affording a stronger and tighter lap-joint. With a construction of this kind little or no deflection or bulging could occur, and the sectional area of the plate and the rings would really give the strength of the boiler.

* Specification No. 14,259.

† Bulletin de la Société Industrielle de Mulhouse, 1861, page 532.

(To be continued.)

MECHANICS, PHYSICS, AND CHEMISTRY.

For the Journal of the Franklin Institute.

The Problem of the Gyroscope. By JAMES CLARK.

NEW YORK, June 24, 1865.

Dear Sir: I enclose you herewith a solution of the problem of the gyroscope, which had occurred to myself before seeing any other, and which, if not novel in principle, I think will at least be found new in method. Further, I think it explains many things left obscure in most of the solutions hitherto published.

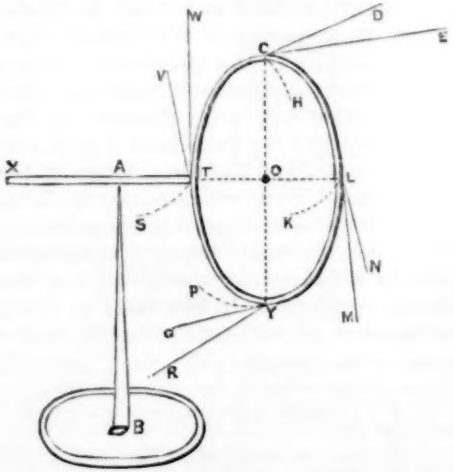
I am induced to offer it for publication at present, among other reasons, because the solution published in the New American Cyclopedia, towards the end of the article "Gyroscope," is palpably erroneous. The writer, in the first place, not recognizing the force generated by the rotation of the spindle about the pivot, as having anything to do with the supporting of the wheel; and, in the next place, he accounts for the rotation of the spindle by the fact that the revolution of the wheel is, on one side, *against*, and on the other, in conjunction with, gravity, both of which conclusions are demonstrably wrong.

Very respectfully,

JAMES CLARK.

The gyroscope, in its simplest form, consists of a wheel or disc revolving on an axle, which rests on an upright pivot, as represented in the annexed figure. When the wheel is set in rapid revolution, and the end of the axle or spindle opposite that on which the wheel revolves is placed on the pivot, the wheel and the end of the axle on which it revolves, will remain supported as indicated in the diagram, and the axle or spindle will rotate about the pivot in a direction opposite to that in which the *top* of the wheel revolves on the axle.

An analysis of the forces producing these phenomena, is what is required by the problem of the gyroscope.



First. What forces produce the revolution of the spindle A O about the pivot A?

If we begin with the particle of matter situated at the point C in the circumference of the wheel, we will find it acted upon by two forces —the centrifugal, which tends to impel it in the direction of the tangent C D, and that of gravity, modified by the suspension of the axle on the pivot A B, the tendency of which is to cause the particle to describe the arc C H. The resultant of these forces, by a well known mechanical law, gives to the particle at C an impulsion in the direction of the line C E, diagonal to the tangent C D and the arc C H*; and the like may be predicated of every particle of the wheel *above* the horizontal diameter T L. The resulting tendency of the forces acting on all these particles, then, is to change the plane of revolution of the wheel to one diagonal to the two planes perpendicular to the horizon, which respectively contain the tangent C D and the arc C H. Now, the wheel can only assume this new plane of revolution, or one parallel to it, by moving *backward* in a direction opposite to that in which the *top* of the wheel revolves, which it is free to do by the rotation of the spindle about the pivot A. If we consider the particle at Y, (and the like is true of every particle situated *below* the diameter T L,) we find it likewise acted upon by the centrifugal force in the direction of the tangent Y R, and by gravity, (modified as explained above,) in the direction of the arc Y P. The result is a tendency to produce motion in the direction of Y Q, the diagonal between the direction of these forces, and, consequently, (Y Q being parallel to C E,) to change the wheel's plane of revolution into the same plane into which it is impelled by the forces acting on the particles situated *above* the horizontal diameter.

We have now accounted for the rotation of the spindle about the pivot A B.

Secondly. It remains to account for the paradox of the wheel's continuing supported in the air.

If we take the particle situated at T, (and the like is true of every particle situated on the same side of the perpendicular diameter C Y,) we discover it is acted upon by the centrifugal force, in the direction of the tangent T W, and by the force communicated by the rotation of the spindle about the pivot A B, in the direction of the arc T S. The result is a tendency to impel the particle at T in a line T V, diagonal to the tangent and the arc, and the wheel into a plane of revolution diagonal to the horizontal plane which contains the arc T S, and the plane perpendicular to the horizon and to the axle A O, which contains the tangent T W.† But the wheel can only assume this new plane of revolution, or one parallel to it, by the *elevation of the extremity* O *of the spindle on which it revolves.* In like manner, the particle situated at L, (and the like is true of all particles on the same side of C Y,) is

* It is, perhaps, not strictly correct to speak of a line as diagonal to a right line and a curve. It would be more exact to say, that the resulting impulsion given to the particle at C, is in the direction of the diagonal between the tangent C D and a tangent to the arc C H at C.

† The spindle is here assumed to be placed on the pivot at right angles with it, which is not necessarily the case; and the angle at which it is placed may subsequently vary, accordingly as the elevating tendency is greater or less than the force of gravity.

acted upon by forces tending severally to impel it in the direction of the tangent L N, and of the arc L K. The evident result is a tendency to impel it in the direction L M, and to produce the *same change* in the plane of revolution of the wheel, that we have already shown to be the effect of the forces acting on the particles on the other side of C Y; and it is this constant *effort* to change the plane of revolution into one which, or a plane parallel to which, the wheel can only assume by elevating the extremity of the axle, which prevents it from falling.*

The whole may be thus summed up.

The rotation of the spindle on the pivot, is the resultant of the action of gravity and the centrifugal force generated by the revolution of the wheel on the axle; while the wheel is prevented from falling by the combined action of the same centrifugal force and the rotation of the axle on the pivot.

COROLLARY 1. If the extremity of the spindle opposite the wheel, be prolonged beyond the pivot in the direction A X, and a weight be placed at X somewhat more than sufficient to balance the wheel, the spindle, instead of rotating about the pivot in a direction *opposite* to that in which the top of the wheel revolves, will rotate in the *same* direction.

COR. 2. If the weight exactly balance the wheel, the spindle will cease to rotate about the pivot.

COR. 3. If the weight be removed, and the rotation of the spindle be stopped by the interposition of any obstacle or opposing force, the wheel will fall.

COR. 4. If the weight be suffered to remain, and be more than sufficient to balance the wheel, and the rotation of the spindle be stopped, the wheel will tilt upward.

OBSERVATION. Another fact remains to be considered, viz: the resistance offered by a body in motion to any force tending to divert or deflect it from the direction in which it is moving.

Suppose a body placed at A, to be impelled in the direction A B, by a force sufficient to carry it to B in a given time. Now, if the same body be simultaneously acted upon by another force in the direction A D, sufficient to carry it to D in the same time, by a familiar law already alluded to, the body will move in the diagonal A C, and will reach C in the same time in which the forces acting singly would carry it to B or D. The point to which attention is invited is this, that while the second force, if acting alone, would impel the body in the direction A D, when the same force acts in the same direction on the body simultaneously impelled toward B, with a force proportioned to that acting in the direction of D, as A B to A D, the path A C described by the body, *more nearly coincides with the direction of the*

* If the spindle be placed on the pivot so as to form either an acute or obtuse angle with it, it is evident that the centrifugal force generated by the rotation of the spindle about the pivot, will *tend* to bring the spindle at right angles with the pivot; in the former case, acting in aid of the elevating force, in the latter, in opposition to it.

stronger force; and if we increase that force, so that it shall bear to the other the ratio of A E to A D, A F, the path of the body will be still more nearly coincident with A E. Whence it follows that *a moving body resists diversion from the direction in which it is moving, and this resistance is in the compound ratio of its quantity of matter and velocity.*

If we apply this principle to a wheel or other body revolving on an axis, and, leaving out of view the thickness of the revolving body, consider that the centrifugal force tends to impel every particle in the direction of a tangent to the periphery of the circle in which it revolves, and that all these tangents lie in the *same plane*, (perpendicular to the axis of revolution,) we can readily perceive that the revolving body will resist any change of its plane of revolution, or, (which is the same thing,) of the direction of its axis, with a power proportioned to the momentum generated by its revolution. If we take the thickness of the wheel into account, we find the particles revolving in a series of *parallel planes*, with a like tendency to resist change.

It is this principle which gives to rifled fire-arms their chief advantage in point of accuracy. If we regard the projectile discharged from a piece of this description as moving in a right line, (which is virtually true of short distances,) its plane of revolution is at right angles to its line of progression; in other words, the axis of revolution coincides with the line of projection. It is evident that the tendency of revolving bodies to preserve the identity or parallelism of their planes of revolution, and, consequently, to maintain the direction of their axes, strongly operates to continue the ball in the line of the original impulsion.

If we apply this law to the gyroscope, it will readily be observed in what manner it co-operates in preventing the wheel from falling. For, one end of the spindle being sustained by the upright pivot, the wheel can only fall by describing the arc of a circle, the centre of which is the point of the pivot and the radius, the spindle. But to fall in this manner, requires a constant change of the wheel's plane of revolution, the tendency to resist which has already been explained.

For the Journal of the Franklin Institute.

A New Process for Extracting Gold from Auriferous Ores, and particularly applicable with great advantage to Pyrites and other Ores containing Gold in small quantities. By H. Jackson and W. A. Ott.

Amongst the different improvements lately adopted for the extraction of gold from auriferous ores, the process of Professor Plattner, of Freiberg, (Saxony,) occupies the first range, as well for its ingenuity as for the advantages to be derived from the same. In this country, on the contrary, the quicksilver or amalgamation process is almost universally practised, and each improvement which possibly could be made has been adopted, so that it may be said the process of

amalgamation has arrived at a point where still better results cannot be expected. Though well known and extensively practised for many years, nevertheless it is not free from considerable defects, which, in relation to economy, never will be obviated. This is a fact generally acknowledged, and the process of amalgamation would have been abandoned if there should exist a more practical and improved mode of extracting gold.

The said process of amalgamation cannot be applied advantageously to the treatment of poor ores on account of the great division or distribution of the gold, thus causing an imperfect contact with the quicksilver, and consequently an imperfect amalgamation. Numerous trials and experiments have proved the impossibility of avoiding these defects, even if the operations of the amalgamation are conducted with the most scrupulous care.

For these reasons Professor Plattner, one of our most ingenious metallurgists, suggested the extraction of gold by means of chlorine, which has been introduced at Reichenstein, (Prussian Silesia,) where immense quantities of certain auriferous residues from the preparation of arsenic had been accumulated since several centuries. These residues being extremely poor of gold, and not fit for being treated by any other known means, nevertheless afforded a considerable profit by the treatment with chlorine.

The same satisfactory results have been obtained at Schemnitz and Schmœllnitz in Hungaria, and other localities, where large hills of residue, formerly considered worthless and thrown aside, are worked over again and every trace of gold extracted.

Plattner, perfectly posted up in theory and practice of all metallurgical operations, soon came to the conclusion that his process might undergo an alteration or improvement in relation to the treatment of natural ores, and especially such ores as contain the gold in a mineralized condition, but, by his premature death, he was prevented from finding out such improvements.

Since Plattner's death nobody on the other side of the Atlantic has taken particular pains to apply his process to the treatment of natural ores, for the reason that gold-bearing ores are comparatively rare in Europe.

In order to explain the defects of this process, we deem it necessary to go into some details, and to report afterwards on the method of extracting gold, for which letters patent of the United States have been granted to us in the month of April, 1865.

Previous to the treatment of chlorine, the ores must be pulverized as finely as those which shall be submitted to the process of amalgamation. Ores containing sulphur must be roasted until all other metals contained therein have been transferred to the highest point of oxidation, being in this condition but very little attacked from chlorine, while gold almost alone will be dissolved. The ore thus first prepared is carried into earthen jars or wooden barrels lined inside with lead, and chlorine gas is passed through the ore so as to impregnate it thoroughly. After this operation, lukewarm water is to be poured over

the ore; the resulting filtered lye of gold is precipitated by sulpho-hydrogen, and the precipitate thus obtained from the sulpho-combination of gold and other metals is dissolved in aqua regis, and by an addition of sulphate of iron the metallic gold will be obtained in a finely divided condition, free from silver or copper and fit for direct melting.

This treatment answers perfectly well for quartz containing gold in very small particles, and for ores containing very few sulpho-metals, and requiring no completely and costly desulphurization, and it answers also for residues, though the apparatus prescribed by the inventor does not allow operations but on a small scale. For treating ores rich in sulpho-metals, like our ores from Colorado, the application of the said process meets with two serious inconveniences, viz:

1. An excess of chlorine is necessary, and
2. The remaining ore is very seldom completely exhausted and contains still some gold.

If we examine specially these two faults, we find that the cheapest mode of chlorinizing would be, if just as much of the chlorine gas could be used as might be necessary for the dissolution of the quantities of gold contained in a certain ore. But that, perhaps, never will be the case, and we always shall need a large portion of chlorine; whereas the finely divided ore, and particularly the oxides therein contained, will absorb the gas without binding it chemically.

According to Plattner's plan of treating the ore, a considerable quantity of gas must be lost, and consequently the expenses will be increased the more as the ability of the ore for absorbing the gas may be very strong, and as the prices of the acids and other materials necessary for the preparation of the gas may range high. If this inconvenience cannot be set aside completely, it is, however, possible to do so partially in a manner we cannot describe here more particularly.

It may be enough to mention that, by applying a peculiar desulphurizing process, we save near one-half of the amount of gas from that required at the works of Reichenstein.

This is the first advantage afforded by our process.

In Plattner's process another inconvenience is to be found in the following:

In consequence of an imperfect roasting and of the existence of basic salts and sulpho-metals, combinations of chlorine and sulphur may be created, which, while producing a secondary decomposition, will exert an influence on the chloride of gold already formed, and will separate a quantity of the metallic gold proportional to the quantity of the sulphur, thus being lost for the process.

A complete roasting, going as far as to remove every trace of sulphur, no doubt would be the best means of obviating this inconvenience, but whoever knows the difficulties occurring in the practice, particularly when operating on copper pyrites, will give up the execution of such a plan.

In our process we obviate the precipitation of the gold in a different

manner, that is, by substituting hypochlorous acid (a gaseous body consisting of 1 eq. chlorine and 1 eq. oxygen) for the chlorine gas, and by submitting the ore to the effects of this gas. The hypochlorous acid gas, when brought in contact with the combinations of sulphur remaining in the ore experiences a decomposition, the oxygen uniting with the sulphur and transferring it into the highest degree of oxidation while the chlorine combines with the gold. By the application of the said gas to the process of extracting gold, we are enabled to secure two important advantages, namely:

1. We obviate entirely the formation of injurious agents by means of the oxidizing effect of the oxygen, and

2. The chlorine is acting while in *statu nascent.* In this state the chlorine has reached the highest degree of chemical affinity, thus making our process (besides its ability of promoting the close of the operation) applicable as well to ores containing gold in finely distributed particles, as to such ores which may contain gold in coarser particles.

Having explained the two chief points which distinguish our process from Plattner's mode, we deem it necessary to say a few words in regard to the question whether it is applicable in a large scale.

Our process requires, like all others, a complete pulverization, and next a good roasting, if the ore should contain sulphur. In case the ores should contain copper, it would be advisable to submit them to a roasting, and to extract the formed copper salt by water, and to precipitate the copper by proper means. In both cases the ore is ready for being treated by the hypochlorous acid.

The question now arises whether this gas can be produced at a sufficiently cheap rate. In view of the enormous quantities of it produced for the preparation of bleaching salts and especially of chloride of lime, we may confidently give an affirmative answer. We do not need for our purposes any other apparatus or localities than those required for the manufacture of the before-mentioned articles, except a leaden retort, which should be placed between the generator of the chlorine and the buildings for the storage of the ore. This retort is filled with a solution of sulphate of soda or glaubersalts, and we thus obtain the hypochlorous acid in a free condition.

The generator of the chlorine in proportion to the impregnating chamber requires smaller dimensions than those necessary for the manufacture of chloride of lime. The impregnating chamber is constructed from silicious sandstone or from bricks in a longitudinal form, and represents a room rather more high than wide. It must be coated inside with asphaltum, and boards 8 to 10 feet long and 2 feet wide should be fastened horizontally along the large sides, one above the other, allowing spaces of about 4 inches between them. These boards are designated for receiving the ore. In the middle of the building a small gangway is to be left; two windows allow to watch the operation, and one door affords admittance to the chamber. A green color will be observed at the windows when the impregnation is completed, and the door thus far tightly closed, then may be opened for the exit of the gas and for the removal of the ore.

The next operation, *i.e.*, the extraction of the ore, is performed either by centrifugal power or by a hydraulic press and water. In this manner we obtain a very concentrated lye from which we precipitate the gold either directly by sulphate of iron, or by a treatment with sulphohydrogen and subsequently by sulphate of iron.

Both operations are very simple and do not require any particular or costly apparatus.

Compared with the process of amalgamation, and in consideration of the expenses for putting up such an establishment being equal, our process, besides the before-mentioned advantages, affords still others, viz:

1. The value of the materials entirely disappearing out of the operations is considerably less, whereas we are working with materials far cheaper than quicksilver.
2. We save great expense of fuel, indispensable for the distillation of the quicksilver.
3. We need no refining, pure gold being precipitated from the solution of the chloride of gold.
4. Our process is not injurious at all to the health of the operators.

Atmospheric Pressure as a Source of Mechanical Power.

(Continued from page 209.)

Fully to appreciate the value of atmospheric pressure as a source of mechanical power, it should be considered not only in contrast but in connexion with the steam engine, and to that the present section is given.

There are some points about steam not generally known, or if known seldom thought of.

1. Quantity for quantity, low steam costs the same in fuel as high steam; or, as laid down in the books, "The same quantity of heat is sufficient to convert the same weight of water into steam whatever be the pressure under which the water is boiled, or whatever the pressure and density of the steam produced."

2. There is the same force in the lowest as in the highest steam; the condensation of the former under a piston exciting an amount of atmospheric pressure equal to the expansive force of the latter against it. In other words, "the same quantity of water converted into steam produces the same mechanical effect whatever be the pressure or the density of the steam."

3. There is no augmenting the natural power of steam. As well might we think of increasing the weight of the atmosphere. To obtain more power from it we call into action more of it, and that is the only means by which additional power is to be had from it. Its force rises and falls with its quantity. A quart compressed into the space of a pint exerts an intenser force than when in the quart, but it is on a smaller surface. The pint can do no more work than the quart. One law governs all forces. A pound weight on a lever

balances several pounds by moving it further from the fulcrum, still it is only a pound with the force of one. So a pound of steam can no more do the work of two pounds than a pound of metal—no more than one horse can do the work of two horses. The pressure within a boiler increases with increased accumulation of steam.

4. The terms *condense*, *condensation*, &c., are apt to convey, to some minds, the same idea as when applied to solid bodies, as rendering metals more dense by hammering or when passed through rollers; whereas, here they indicate the production of a void by the vapor shrinking into a minute part of the space it filled—as gallons of steam into thimblefuls of water.

The foregoing borne in mind, all that follows may be understood by others than practical men. They will perceive two forces in steam, of which one begins to act as the other ends; and that its power continues from its birth in the boiler to its last gasp in the condenser. Moreover, that heat is the element of force and steam the agent or medium by which it acts, and consequently fuel only is consumed and has to be renewed. A small quantity of water might furnish an indefinite amount of steam. Being revived in the boiler as fast as it expired in the condenser it might circulate through them forever.

The great lever of modern civilization and essential to its progress, steam has immeasurably more work to do than it has done. It has to be cheapened, and to effect that more work has to be got out of it. Rich in that which is the source of all wealth, its economical applications are among the most important desiderata; for the fact is incontrovertible, though almost incredible, that not over *one-third* of its power has yet been utilized, consequently two-thirds of the fuel expended upon it are lost.

Like the permanent gases, steam is a fluid *spring*, differing from solid ones in the form of its action. Instead of bending to and fro, it swells and shrinks. In the range of its movements it surpasses those made of metal. They are derived from ores; it comes from water, of which one volume swells into seventeen hundred and shrinks back into one. No clearer idea of its capacity and functions can be had than by considering it as an elastic instrument of motion. Heat winds it up and cold unwinds it. Like other springs it has two movements, equal in power, but in opposite directions, and both must be used. To neglect either is to lose half of the power. For high-pressure motors the spring is wound up and allowed to run down to waste, while for an atmospheric one the shrinking movement is used and the swelling one passed by as if of no account.

There can therefore be no doubt, however valuable atmospheric engines may be for particular purposes, that the truest application of steam, as an agent of force, is to associate high pressure engines, the greatest wasters of it, with atmospheric ones which blow off none. All the heat will then be utilized, and when that is done practice will conform to theory and be perfect.

As the two movements or forces bear the same relation to each other as action and reaction, if the amount of one be ascertained it

must be the same as that of the other; hence if the expansive power is not easily traced to the vanishing point, we know exactly what it is by the vacuum condensation produces. They have given rise to two classes of engines, high-pressure or non-condensers and condensers.

Non-condensing engines, the most numerous and popular, are operated solely by the swelling or expansive force, and consequently cannot turn to account more than half the power in it. They do not, however, do that nor anything like it. There is a mechanical difficulty in the way, the consequence of which is that they utilize only about half the expansive force, and therefore only *one-fourth* of the power. A cubic inch of water evaporated under a piston raises a ton a foot high; there the force and resistance are balanced, and there the piston of the engine stops; the force remaining in the fluid being dispersed with it for lack of means to use it. A steel spring half uncoiled can be removed and its unexpended force employed, but engineers do not yet know how to do that with steam that has spent part of its force in the cylinder of an engine.

To lessen the loss, most engines "work steam expansively." That is, the cylinder is only partially charged, by cutting off the communication with the boiler at certain stages of the stroke, the portion admitted being left to dilate and follow up the piston to the end of the stroke. The alleged gain from this arrangement is considerable. It would be complete instead of partial if expansile and contractile pistons, working in conical instead of cylindrical chambers, could be used, as they would present enlarging areas to decreasing pressures, and receive and impart a full and equable effect from a varying force. The device, however, is apparently not within the range of our present mechanical appliances.

The amounts of expansive force escaping in the volumes of waste steam from high pressure engines are obvious. Whether the European estimate of this loss be exaggerated or not, the fluid goes through such as make 50 strokes and upwards per minute, with great rapidity. The piston acts but as a momentary check on its passage from the boiler to the waste-pipe. The temperature and amount can be but little reduced.

Of the vast and increasing numbers of high-pressure engines there is perhaps not one proprietor in a hundred prepared to believe that in his waste pipe he throws away as much power as he realizes; and if next told that the amount is nearer twice as much, derision would probably succeed to incredulity. The clouds of steam ascending daily from engines located on the East and North Rivers, afford such proofs of economy, as dumping off the docks half the quantity of coal consumed in heating their boilers would be.

Condensing Engines.—These call into action both forces, and, strange to say, they yield little more than half of one of them; and this, too, in the face of the fact that, while there is a difficulty in the way of obtaining the entire expansive force, there is none whatever in realizing by condensation the whole of the contracting force. Lard-

ner, in his work on the Steam Engine, thus speaks of both classes:—

"In engines which do not condense the steam, and which, therefore, work with steam of high pressure, some of the sources of waste are absent, but others are of increased amount. If we suppose the total effective force of the water evaporated per hour in the boiler to be expressed by 1000, it is calculated that the waste in a high-pressure engine will be expressed by the number 392; or, in other words, taking the whole undiminished force obtained by evaporation as expressed by 10, very nearly four of these parts will be consumed in moving the engine, and the other six only will be available.

"In a single acting condensing engine, taking, as before, 1000 to express the total mechanical power of the water evaporated in the boiler, 402 will express the part of this consumed in moving the engine, and 598 therefore will express the portion of the power available; or taking round numbers, we shall have the same result as in the non-condensing engine, viz: the whole force of the water evaporated being expressed by 10, 4 will express the waste and 6 the available part.

"In a double acting condensing engine, the available part of the power bears a somewhat greater proportion to the whole. Taking, as before, 1000 to express the whole force of the water evaporated, 368 will express the proportion of the force expended on the engine, and 632 the proportion which is available for the work.

"In general, then, taking round numbers, we may consider that the mechanical force of four-tenths of the water evaporated in the boiler is intercepted by the engine. In this calculation, however, the resistance produced in the condensing engine by the uncondensed steam is not taken in the account: the amount of this force will depend on the temperature at which the water is maintained in the condenser. If this water be kept at the temperature of 120°, the vapor arising from it will have a pressure expressed by three inches seven-tenths of mercury; if we suppose the pressure of steam in the boiler to be measured by 37 inches of mercury then the resistance from the uncondensed steam will amount to one-tenth of the whole power of the boiler; this added to the four-tenths already accounted for, would show a waste amounting to *half the whole power* of the boiler, and consequently only half the water evaporated would be available as a moving power.

"If the temperature of the condenser be kept down to 100° then the pressure of the uncondensed steam will be expressed by two inches of mercury, and the loss of power consequent upon it would amount to a proportionately less fraction of the whole." Again, "If the direct force of high pressure steam be combined with the indirect force produced by its condensation, the total mechanical effect will be precisely equal to the mechanical effect of the condensation of atmospheric steam."

That is, six-tenths is the sole practical value of *each* of the forces, *and of both combined!* Less than one-third of both. Whereas, if the contracting force did not disappear, somehow or other, in the engine,

the result should and would be over two-thirds instead of less than one.

Hence the question naturally arises—If condensing engines produce no more power than non-condensing ones, why employ them at an increased expense of machinery and of power intercepted by it; and if the expanding and contracting forces produce, when combined, only the effect of one, why use them in combination? Is there not something here that wants explaining? Force within an engine that does not come out must be absorbed by the mechanism or neutralized by its arrangement. We know that separately the two forces act perfectly, and hence when their united effect is not double that of one of them, it can only be ascribed to their combination.

There is no difficulty in collecting separate forces into one motive power, like affluents of a river into a single channel, when they coincide in their bearing or course, but it is otherwise when they move in opposite directions. To make such coalesce they must be separately evolved. How can two conflicting ones as heat and cold, shrinking and swelling, be combined without their joint effect being less than their separate action? Can anything be more certain, than that steam discharged from a non-condensing engine will, as readily as direct from a boiler, produce as much more power if passed into an atmospheric cylinder? Compact machinery is a favorite doctrine, but it may be carried too far. The condensing steam engine is an example.

Heat not used up is wasted, but theory tells us it ought to be wholly utilized. How is that to be done? In the way that nature does it—by first using the expansive force and then deriving an *equal* amount from contraction.

Now, while the indirect force of steam in shrinking into a liquid equals its direct pressure against a piston, how is it that condensing engines are not more productive? Because they condense *compressed steam*, and *limit the effect of the vacuum to the area of the piston*. Perhaps it will be said that when an engine is worked with 30 or 60 pound steam it does not follow that such is its tension on leaving the cylinder, since in most cases it is reduced by expansion through the operation of the cut-off. Granted; yet it cannot be reduced below the resistance, so that at whatever tension it is above that of atmospheric vapor, just so much is wasted, so much power thrown away. But suppose it dilated till barely sufficient to balance the atmosphere; what then? would not the effect be the same as long as the vacuum is confined to the piston? If several cubic feet of common steam be compressed into a cubic foot, would not *each*, on being released, swell into its previous volume and be as valuable for producing a vacuum in a working cylinder of the capacity of a cubic foot as the condensation of the whole of them in it? That is what our engines should be made to do; instead of which they extinguish the life in several volumes for the sake of one, and consequently get no more than the effect of one out of them. This is that which enfeebles them, nor can it be removed except by using steam too weak to move the piston at all. It is ex-

pensive as well as inherent; for in condensing more than is necessary there is a loss of power, and a loss that increases with the excess. It would be better to blow off the surplus, if that could be done, than to waste power over it. Such is the result of a misalliance, or vicious combination, of expansion and collapsion in *the same cylinder.*

Is it asked how the evil is to be avoided? By cutting off the communication between the condenser and working cylinder, and discharging the steam from the latter into an atmospheric one, its capacity being determined by the intended pressure of the steam, or the number of times it will admit the working cylinderful of high or compressed steam to expand into low, or uncompressed. Thus, an engine working with 60 lbs on the inch, one cylinderful would expand into four at common or atmospheric pressure, at 90 lbs into six, at 120 lbs into eight, at 150 lbs into ten. Whatever the number, it will be found that the force evolved by condensation is equal to that of expansion. For example, a cylinder working with steam of 60 lbs. and the area of the piston 50 square inches, the expansive pressure will be $60 \times 50 = 3000$ lbs. On the other hand the fluid would fill four cylinders of the same dimensions, or one with a piston of four times the area; hence $50 \times 4 \times 15 = 3000$ lbs. of atmospheric pressure. By the present system the vacuum, instead of yielding 3000 lbs., would probably not yield 300. According to the authority quoted —which has not been questioned—it would yield little or none.

Whatever other advantages may be claimed for the condenser of Watt, as respects economy of power it was a decided failure—the continued use of which can only be accounted for on the ground of passive and unreflecting obedience to his rules. He appears to have been embarrassed by the claims of the two opposite forces, and made a compromise between them instead of giving each its full scope by itself. The air-pump crippled both. It took steam to work it, and produced no better vacuum than Newcomen had without it. It checked the employment of high and even steam of medium pressure. But for it, he would have made more manifest an alleged preference of the expansive over the contracting power. A philosphical friend gave currency to the statement, that his condenser was originally suggested as an economical appendage to Newcomen's engine. This he contradicted, saying: "From the first I intended to operate with steam instead of the atmosphere, and my apparatus was so constructed." (Stuart's Anecdotes of Steam engines.)

Notwithstanding this, "the three great steps in the brilliant career which has immortalized his name," had every one of them reference to atmospheric pressure: 1. Condensing in a separate chamber was to avoid the cooling of the cylinder by the jet playing in it. 2. Maintaining the vacuum by the air-pump and its accompanying hot and cold water pumps. 3. Closing the open end of the cylinder to avoid the cooling effects of the air on pushing down the piston, and requiring, as in the case of the jet, more steam on the ascent of the piston to reheat it.

The leading inquiry in discussing the value of motive forces is not what power *is* got out of one, but how much *can* be got out of it. We

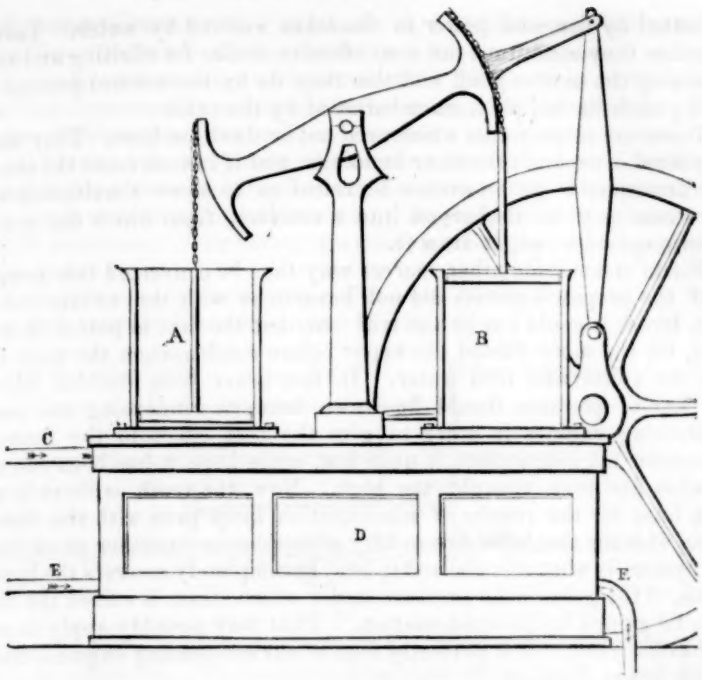
know exactly how much there is in steam, high or low. If Watt had used the former, and passed the steam from his cylinders into atmospheric ones he would have left little for his successors to do.

Of fourteen marine engines built by one firm in this city, the average cylinder is 45 inches diameter, with 8½ feet stroke; the air-pump 30 inches and 3½ feet stroke. All, except three, are calculated to work with steam up to 30 lbs. on the inch; hence every cylinderful at that tension contains three of common or uncompressed steam, and, when condensed as one, two-thirds of the power which might be drawn from it are lost. The cylinder holds 93 cubic feet, the condensation of which ought to contribute an amount of force equal to 93 tons raised one foot. We know it does not and cannot yield half of it; yet that amount ought to be doubled if the vacuum were produced in separate cylinders.

When the subject is duly considered, the inducements to adapt condensers to atmospheric cylinders, can hardly be resisted, as generally double the power will be obtained with no extra working expense but that of ice or water for condensation, and not even that for adding to the power of *marine engines*, as they have it without pumps to raise it. As the power increases with the pressure of the steam, such engines instead of 30 lbs. on the inch may be safely reduced in their dimensions and worked at double or treble that amount. None can more readily and beneficially realize the change. Their steam cylinders may be converted into atmospheric ones, and replaced with others one-third or one-fourth their size. Economy as respects space is not more obvious than in fuel and power. To increase the power of a steamer's engine at present, she must take in a larger cargo of coal; on the plan here presented she need not take in an additional bushel.

Invaluable beyond expression as steam power is, and is to be, it is strange that atmospheric pressure has not been more cultivated. It is uniform, while that of steam is variable and always less in the cylinder than in the boiler. The full effect of the vacuum is obtained on the easiest terms, whereas from the direct pressure of the steam there is a heavy discount. Make all engines on the proposed plan, and the steam power of the world may be doubled, if not more than doubled wherever water is cheaper than coal; and, as with marine engines, requires neither cartage nor stowage.

To engineers it would be superfluous to add anything more; but there are those who do not perceive how fresh force is to be got out of waste steam without fresh fuel, nor how it is to be used. They want something more to make the matter clear to them, and for that purpose the annexed figure is introduced. They understand how one force is the production of heat, and it will explain how the other is evolved by cold, or the abstraction of heat. The steam cylinder is left out, as its action requires no explanation. Its waste pipe is all that is wanted to supply the steam that is to be converted into power. A portion of it is represented.



A and B are sections of two atmospheric cylinders open at top, each being two or three times the capacity of the steam cylinder, according to the pressure of the steam used. C, the waste steam-pipe; D, the condenser; E, the cold water pipe; F discharges the heated water. The positions of the pistons indicate that the steam piston has just descended in its cylinder and discharged its contents into B. On being condensed, the piston of B is pressed down by the atmosphere and that of A at the same time raised to receive the steam from the upward stroke of the steam piston, which, on being in its turn condensed, excites the pressure of the atmosphere to press down the piston of A and raise that of B. The fly-wheel, as usual, carries the crank over the dead points. The valves to admit the steam alternately into A and B, and those that turn on and off the condensing water, are too well known to require being figured.

Of course it makes no difference whether the steam cylinder be horizontal or vertical, fixed or oscillating.

As the atmospheric pressure on the pistons of A and B is limited to their downward stroke, their rods are here represented as connected to the vibrating beam by chains. But as the force of the steam on first entering will suffice to raise them through a considerable part of the stroke, which is so much power gained, the connexion should be made in the usual manner.

In this way the two forces may operate two distinct engines, one

animated by fire, and power in the other evolved by water. Taken together they constitute the most effective device for eliciting and economizing the motive fluid, and this they do by the natural process of giving each its full play, unembarassed by the other.

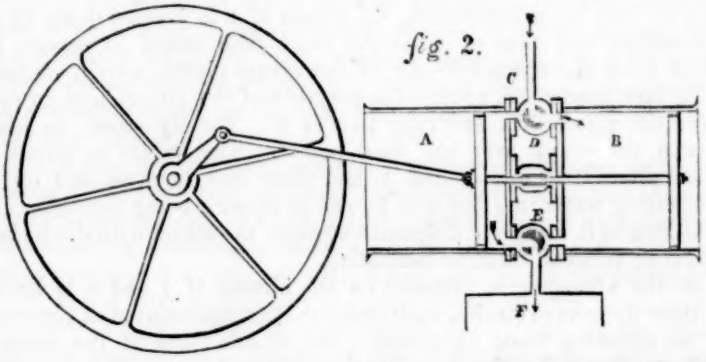
There are other points which need not be dwelt on here. They may be placed in separate rooms or buildings, and if in such cases the steam and atmospheric piston cannot be relied on to move simultaneously, the steam may be discharged into a receiver, from which the atmospheric cylinders might draw it.

Waste steam from other sources may thus be converted into power.

If the proposed system did not harmonize with the exhaustion of both forces it could not be the true one, but the fact is patent that it does, for the more dilated the vapor before condensation the more facile its conversion into water. It has never been decided where the line of pressure should be drawn between condensing and non-condensing engines in order to give the best effect to the former. European engineers place it quite low, while here it has been run up to what has been thought too high. Now, the truth is there is no such line, for the results of condensation keep pace with the direct force, whether that be of five or fifty atmospheres—another proof that the system is what it is claimed to be. It completely *reverses* the hypothesis, "the greater the pressure under which steam is raised the less is to be gained by its condensation." That may possibly apply to superheated steam. It is perfectly true of our condensing engines, from which it was deduced.

Fig. 2—a mere variation of the preceding one—will serve to show how the proposed plan comprises the exhaustion of the *expanding* as well as the contracting force. This has hitherto been deemed unattainable, and, but for the system of condensation in separate cylinders, it would still be an impossible problem.

fig. 2.



The cylinders, A, B, are horizontal, and both pistons attached to one rod, which passes through a stuffing-box connected to the closed ends of the cylinders. C supplies the waste steam; D, a valve or three-way

cock, communicating with C and A, B; E, a similar one, with passage from the cylinders to the condenser, F. Suppose the steam cylinder (not represented) working with steam of 60 lbs on the inch, its piston half the diameter of A and B, and with the same length of stroke. The arrows indicate the passage open between A and the condenser, and steam passing into B, against whose piston it acts in unison with the atmospheric pressure moving forward the piston of A. Thus the steam in B keeps expanding *with the receding piston* till its force expires at the end of the stroke. The valves are then reversed, and the same thing takes place in A.

Let experience determine the difference between engines on this plan and those of Hornblower and Woolf.

fig. 3.

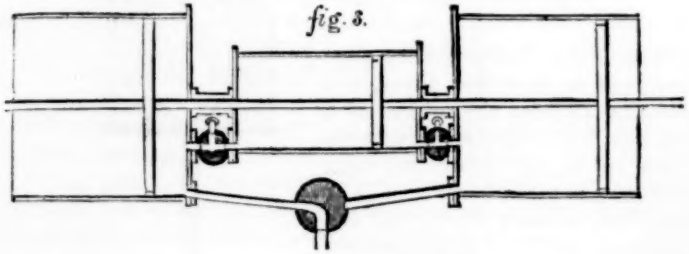


Fig. 3, outline of an engine in which the steam and atmospheric cylinders are combined. To engineers details are unnecessary. The steam cylinder is placed between and on a line with the atmospheric ones, and connected directly with them. The three pistons are on the same rod —the steam and exhaust valves, and stuffing-boxes—as in Fig. 2. By such an arrangement side-pipes are got rid of, and also the additional waste of steam for "clearance," there being no chance for water remaining in the cylinders to arrest the pistons.

There are those who question the *rationale* of the popular cut-offs. If no more steam enter a cylinder than sufficient to overcome the resistance, it matters little whether it enters at once or flows in to the end of the stroke. In the latter case, the motion is equable, and the engine not strained by varying the momentum. Hence, the alleged gain, it is said, can only be the per centage of power unnecessarily employed at the first part of the stroke. Leaving the question for others to settle, it is enough to observe that by using steam as here proposed, expansion may be carried to an extent that will, in a great measure, if not wholly, supersede the use of cut-offs. No power can be lost by their non-usage.

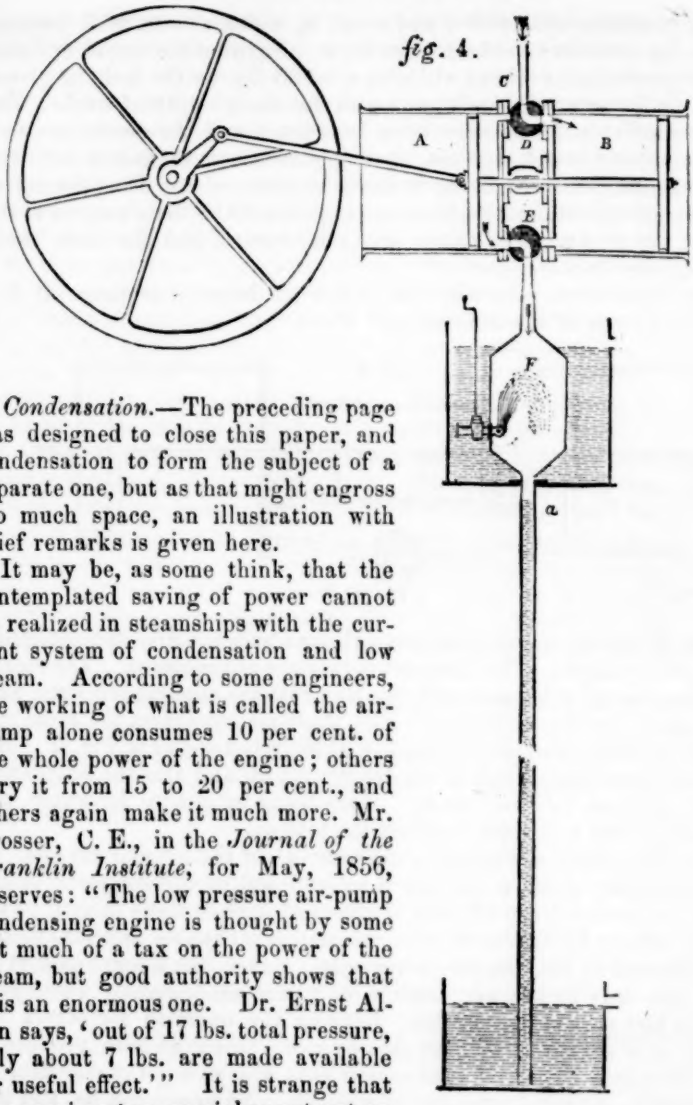


fig. 4.

Condensation.—The preceding page was designed to close this paper, and condensation to form the subject of a separate one, but as that might engross too much space, an illustration with brief remarks is given here.

It may be, as some think, that the contemplated saving of power cannot be realized in steamships with the current system of condensation and low steam. According to some engineers, the working of what is called the air-pump alone consumes 10 per cent. of the whole power of the engine; others vary it from 15 to 20 per cent., and others again make it much more. Mr. Prosser, C. E., in the *Journal of the Franklin Institute*, for May, 1856, observes: "The low pressure air-pump condensing engine is thought by some not much of a tax on the power of the steam, but good authority shows that it is an enormous one. Dr. Ernst Alban says, 'out of 17 lbs. total pressure, only about 7 lbs. are made available for useful effect.'" It is strange that an *experimentum crucis* has not put an end to such diversity of opinions on a matter so important. If any such have been made I know not where to look for them. I cannot, however, resist the conviction that a thorough investigation will lead, sooner or later, to the abandonment of "low" steam.

It is proposed to maintain the vacuum by the same power that acts upon it—by connecting the condenser with a pipe having a perpendi-

cular descent of about 36 feet; its lower end dipping into water in a vessel containing somewhat more than sufficient to fill it. See fig. 4. The vacuum resembles that in the cylinder of a suction-pump, placed too high for the weight of the atmosphere to raise water into it. Whatever amount of condensation takes place in the condenser, the length of the liquid column will continue the same, its upper surface never rising above *a*, however copious the liquefaction of the steam. The vapor evolved in the vacuum from so small a surface will be insignificant, and may be reduced, or its evolution checked, by a stratum of oil, which could be but slowly dissipated, as there is no escape for it except by descending through the entire length of the pipe.

The air contained in the water would, of course, not be thus got rid of. For that purpose a syringe or small pump would be required. Suppose the amount, as some assert, 5 per cent. of the water injected, hardly 5 per cent. of the force now expended on the withdrawal of it and the water could be wanted.

The temperature of water in present condensers is sometimes as high as 120°, the vapor from which has a back pressure of between 3 and 4 inches of mercury; and when the pressure in the boiler is 37 inches, the loss of power is one-tenth. By the plan here sketched no water collects in the condenser, and the temperature, when water is abundant, may be reduced to 80°, and with ice still lower.

For stationary engines there can be little difficulty in providing for the pipe's descent. When located on ground floors in cities there are cellars and often under-cellars, and in the country wells are common. The pipe itself need not be vertical, provided the requisite depth is secured.

It is proper to state that this mode of maintaining the vacuum is not a new conception. It was proposed in Arnott's Physics many years ago, but is supposed never to have been put in practice. An adaptation of the principle to marine engines would be of surpassing value, nor does there appear an insuperable difficulty in giving to the condenser, at least in some cases, a sufficient elevation above the engine.

But one resource more appears open to reduce the enormous force expended on condensing machinery, and that is to use ICE as the cooling agent for the reasons assigned in the first part of this paper, (p. 207, vol. xlix.) That something approaching to two-thirds of the water now required, and, with it, a like proportion of the power would be dispensed with, need not be questioned. Instead of the water in steam requiring twenty times as much for condensation, Mr. Sewell, C. E., declares, in his article on "Surface Condensers," *Jour. Frank.*, vol. xliv, p. 348, "that more than double the amount is sometimes necessary. The quantity of water necessary to condense a certain quantity of steam varies as the temperature thereof, the colder the water the less quantity is necessary, being from fifteen to *forty-five times* that contained in the steam. . . . . To relieve the engine of this enormous load, it is found to be of advantage to use less injection water to condense the

steam, and consequently get less vacuum, the loss of power from this cause being less than when the air-pump is overloaded."

Another advantage of ice for internal condensation arises from the fact that "air combined with ordinary water is discharged in the act of freezing." Hence, there will be little to pump out.

To prevent premature condensation in the cylinders A B, besides enveloping their exterior in non-conducting wrappers, I would introduce into them cylindrical linings of vulcanized rubber, as already suggested: (page 208,) molded on polished cores they are comparatively inexpensive.

To conclude: If it be a truism that the two forces—expansion and contraction—bear the same relation as action and reaction, ignoring the latter in our high pressure engines, and then turning to account little over half of that, reflects no credit on us. The blunder cannot, we believe, be tolerated through another generation, although there are some who consider the proposition to reduce the loss of power, by making two-thirds available in place of one-third, as bordering on the chimerical, as if the elements to accomplish what is proposed were lacking—as if the saving of that which is palpably thrown away was impossible and the attempt preposterous. Economists, to scraps, of wrought and unwrought materials we are wholesale spendthrifts of that which gives value to them. Our engines will certainly be referred to hereafter as characteristics of the dawn, or early days of steam power. If the plan here suggested to improve them be deficient, as it well may be, let others be tried till success is attained, for progress is certain, and though it depends on steam it can never lack those who are keen to detect and resolute to remove obstacles in its path; who, to use a Scriptural phrase, press onward to perfection, by casting off things that are behind (the age), and reaching out to those that are before.

P. S.—In the present condition of national affairs a brief allusion to a kindred topic may be permitted. Our planet is a school for engineers, as for other professions. It is alive with illustrations of mechanical laws, as fixed and immutable as the universe itself; and nothing is more certain, that only so far as our devices accord with them can they succeed. Thus it will be, as heretofore, with the propelling blades of a steamer as with the force that propels them. Abortive *must* be all attempts to make her speed what it ought to be as long as the principle of *form* so distinctly and variedly manifested in organisms that move rapidly through air and water is ignored. It is fundamental. No finite intelligences can improve or supersede it. There is marvellously more in it than common observation perceives. It governs other attributes. Endless are the projects on minor points, and all of them fruitless for lack of that which only can give value to any. An increased speed of three or four knots would have virtually ended this horrible war two years ago, saved thousands of lives, and multiplied millions of money. It may just as well be attained as the current rates of speed, and it will be, though apparently not without some further struggling against a plain law of physics—plain and perfect to

those who look into it, a stumbling-block and foolishness to those who do not.

Every horizontal section of a blade has a different velocity, and, to make the resistance and effect uniform, its width must *diminish with the dip*. The centre of resistance, instead of being near the extremity, will then be drawn in towards the centre of the blade, and economy of force will result. There is, in fact, a reciprocal influence pervading every part, every feature and movement of a perfect blade; and wherever this harmonious action does not exist, loss of speed and waste of power are and will forever be inevitable, for physical laws are eternal. There are some things which the present state of the arts cannot accomplish, but there is no physical obstruction whatever to our giving to sea-boats a maximum speed with a minimum of force—to rivalling in this respect the ablest engineers of the future.

On Certain Methods of Treating Cast Iron in the Foundry. By ZERAH COLBURN.

From the Lond. Civ. Eng. and Arch. Journal, May, 1865.

The short notice given me for the preparation of this paper, together with the fact of my almost constant engagements, must serve to excuse any apparent haste in the treatment of the subject, as well as the absence of diagrams. I had thought of writing upon iron founding, and, to a certain extent, I have done so, but the term "iron founding" would hardly include some things of which I shall now speak, and hence I have chosen the title already announced.

Beginning with the plant of the foundry, something may be said of the cupolas and of the blast apparatus. The cupola furnace is still much the same as described by John Wilkinson, who patented it in 1792. His smelting furnace (and smelting is from the Dutch word *smelten*, signifying melting only, and not necessarily the extraction of ores) was, to use his own words, "made very low, about 10 feet high, of cast iron plates bolted together and lined with fire-brick." A strong blast was introduced through one, two, or more tuyeres. In 1820, one William Taylor patented the use in blast furnaces of several tuyere holes, at various heights and in different sides of the furnace, for the admission of the blast to insure its equal distribution. The same idea is, of course, equally applicable to cupola furnaces, to which it has been applied by Mr. Ireland, of Manchester, in his "upper tuyere" furnace. That there is any real advantage in the upper tuyere furnace is still denied by some of those who have used it, and it is difficult to say wherefrom any substantial advantage should result. One of Mr. Ireland's cupolas, measuring 4 feet in diameter outside and 22 inches in diameter in the hearth or crucible, has 3 tuyeres of 6 inches diameter, and about 20 inches above these 8 tuyeres 2½ inches in diameter. A strong blast has much more influence than the subdivision or distribution of the blast, and we know that in blast furnaces enormous masses of ore, coke, and limestone are penetrated by a blast of moderate pressure from a few tuyeres arranged in a single row around

the hearth. In the United States a number of cupolas have been made of late years and used with considerable success, with an annular opening or port ¾ of an inch to 2 inches wide, around the whole inner circumference of the furnace, and with some of these furnaces with which I have had to do, their horizontal section was elliptical, measuring 9 feet by 3½ feet internally; and with a blast equal to 10½ inches of water, or ⅜-pound per square inch, they brought down 12 tons of iron per hour. The full charge was 21 tons, which could always be brought down in 2 hours after turning on the blast, the annular tuyere or port being nearly 20 feet in length around the furnace, and 1¼ inch wide, although a large part of this great tuyere area of, say, 2 square feet, is obstructed by the charge in the furnace itself. Had I time to do so I should have been glad to have prepared diagrams of these cupolas from the working drawings in my possession. The elliptical section of furnace was adopted many years ago in cupolas in some of the German iron foundries, and it was revived in Alger's blast furnace, of which a good deal was heard in England about eight years ago. It cannot be asserted that this has any advantage, while it clearly has certain disadvantages in increased surface and cost of construction. The object sought in the elliptical furnace is that of containing a large charge with but a moderate distance between the opposite sides of the furnace, but here an increased pillar of blast will fully compensate for any increase of distance from the tuyere to the centre of the charge.

I have always believed that a decided advantage would result, in the case of cupolas, by having the drop bottom in general use abroad. I doubt if there are a dozen cupolas in America with the irremovable bottom as adopted in English practice. The severe labor in raking out the bottom of an ordinary cupola would be saved by the drop bottom, where the mere withdrawal of the bolt sends whatever is in the furnace into a pit below. The American cupolas are built upon a cast iron base ring, which is supported upon three cast iron columns, at a height of, say, 2 feet above the foundry floor. This base ring is of the external diameter of the cupola, say, 5 feet, and in its internal diameter is that of the circular trap door known as the drop bottom. The trap door will be, say, 2 feet in diameter, 1½ inch thick, and having a coombing 4 inches high carried around its upper edge to receive a paving of fire-clay or a round fire-clay tile to support the charge. In my own practice, I have hinged this door by 1½-inch hinge bolt, 28 inches long, with a stout head at one end and a cotter in the other; the lugs or ears in the door and in the base ring were each 4 inches long, and of good thickness. The door was held up by a draw bolt, passing through staples of great strength in the base ring, the bolt being of 3 inches by 1½-inch iron. It is often said, "What if such a trap door should give way, with from three tons to ten tons of iron in the cupola?" Such accidents never happen, nor would they be attended with any great danger if they did happen. The iron might be lost, but that would be the worst of it. To shut the trap door a stout wrought iron stalk descends from its centre for 18 inches, a heavy ball being fixed upon the end of this staple. A chain is attached to this ball,

and the drop or trap can be thus easily moved by hand when the draw bolt is out.

After the cupola an improvement is desirable in the blast apparatus. The rotary fan is in almost universal use in foundries. In order to obtain a pressure of 20 inches or 24 inches of water, with 3 square feet of tuyere opening, a 3-feet Lloyd's fan is usually driven at from 1500 to 1800 revolutions per minute, the tips of the vanes moving, say, at the rate of nearly 3 miles per minute. From fifteen to eighteen horse power are required, and with an old-fashioned fan much more. Besides the power there is to be considered the wear and tear of straps running at a high velocity. For considerable pressures of blast, to which foundry practice is tending, the direct compression of the air by a piston is more economical than the fan blast. For a blast furnace, of course, no form of fan would be practicable at even a pressure of $2\frac{1}{2}$ pounds per square inch, still less at 5 pounds to 6 pounds, as is occasionally employed. I have seen a steam blowing engine used with excellent results in a large foundry where the air cylinder was in a line with the steam cylinder, both the steam and the air pistons being fixed to the same rod, while a pair of connecting rods worked a fly-wheel to carry the engine over the centres. The same class of blowing engines, working at an air pressure of from 15 pounds to 20 pounds per square inch, is now employed by Mr. Bessemer in blowing air into his converters. For more moderate pressures, however, a rotating apparatus is preferable. In gas-works, where the difference of pressure in the retort and in the purifyers is, perhaps, 1 pound per square inch, it is usual, in the London works at least, to employ Beale's exhausters. No gas engineer would think of employing a fan for exhausting. Mr. Beale's exhauster is constructed somewhat upon the principle of a rotary pump, patented by the late Mr. Siebe, a father of the present Mr. Siebe, in 1828. This pump has been reproduced in the States as Cary's pump, and it was the water-pump adopted in the American steam fire-engine exhibited in the International Exhibition of 1862. An almost identical machine for pumping air instead of water, is now in extensive use in American iron foundries under the name of M'Kenzie's blower. Many of my friends who have used these blowers prefer them to fans, as taking less power, while they are, of course, capable of working at any pressure of blast required. One of those blowers, now at work at a locomotive factory of which I was engineer in 1854, is 26 inches in diameter, 3 feet 6 inches long, and at a speed of 100 revolutions per minute, blows against a pressure of 21 inches of water in supplying a large cupola. The power required is found to be much less than that consumed by a fan, especially at high pressures, while the wear of straps is very moderate, the lineal rate of the driving strap being now about 300 feet, instead of something like a half a mile a minute, as with a fan.

I shall devote the further portion of the present paper to the consideration of—1. Means for increasing the strength and hardness of castings. 2. Means for insuring uniform cooling in castings after pouring. 3. The treatment for malleable castings. 4. Chilling.

At one time, when cast iron was employed for boilers, shafting, large ordnance, and bridges, its strength was of great consequence. It has now become usual to employ wrought iron or steel for the applications just named, and, indeed, wherever great absolute strength is required. Even engine beams, since the lamentable failure at Hartley, are being made of wrought iron. So the importance of great strength in castings has no doubt been lessened; and for most purposes it has been found cheaper to employ a somewhat larger quantity of ordinary iron than to pay a higher price and incur the delay often attending the search for a superior quality. For many purposes, indeed, as in engineer's tools, a liberal allowance of metal is requisite to secure stiffness,—a kind of stiffness better provided in such cases by inertia, or mere dead weight, than by the absolute resistance of the metal per square inch. Yet there are still purposes, as in the case of railway chairs, water pipes, columns, &c., without mentioning hydraulic press cylinders and steam cylinders, where great strength in cast iron is of much importance; and cast iron is still the material principally employed in America for cannon of 13-inch, 15-inch, and in recent instances even 20-inch calibre. This is not the cast iron, however, of which guns have long been made in England, and were it not indeed greatly superior to our own, it would never withstand the proof and service charges which the heavy ordnance in question is known to bear. The report of the chief of ordnance in the United States Navy gives the service of one of the 15-inch cast iron guns as follows: It was fired 900 rounds with a 440-pound solid shot. The charge of powder, at first 35 pounds, was successively increased to 50 pounds, 60 pounds, and 70 pounds. With 60-pound charges 220 rounds were fired, and the gun only burst with a 70-pound charge and 440-pound shot at the end of 900 rounds. It is doubtful if even as good results have been, or will be, attained by the most carefully wrought iron guns of the same calibre. Upwards of 100 of these 15-inch guns are now in service. Before going on with the consideration of how such great strength in cast iron is attained, it may be as well to give the following notes of the 20-inch cast iron guns, of which a number have already been made. They weigh 51½ tons each, and the first of these guns was 13 days in cooling. They are 20 feet 3½ inches long over all, and 17 feet 6 inches long in the bore. Their greatest diameter is 5 feet 4 inches. They are fired with 100-pound charges of powder, and a solid shot weighing 1000 pounds.

I shall say nothing of the selection of particular brands of iron, nor of the great importance of proper mixing in the cupola, for I could only say, what every qualified founder well knows, that upon these a great deal depends. I could give no direction better than those upon which founders now act, each having to choose and mix the irons which he has found best for his own purposes in his own district, for it is always important to him not to send further than is necessary for his pigs. But there are modes of increasing the strength of a large number, if not all, of the irons known to commerce, and although there is still much doubt as to the relations between the chemical constitu-

tion and the strength of iron, it is certain that all the known modes of strengthening cast iron are modes whereby its proportion of uncombined carbon and of silicium is known to be diminished. If we puddle cast iron up to a certain extent, and stop at the right point, we have steel of very great strength, and if we carry the puddling far enough we have wrought iron. So if we melt cast iron with wrought iron, as in making what is called Stirling's toughened metal, we lessen the relative proportions of the impurities to the iron as contained in the pig, and if we do not get a remarkably tough metal, we, at any rate, produce one of great hardness, and some of our locomotive makers employ such a mixture purposely to obtain hardness in their steam cylinders. So also, by oxidizing cast iron at a high heat, as in the treatment for malleable iron castings, we gain undoubted strength and toughness. Here, too, the carbon and silicium of the iron are lessened in quantity, and so it may be apprehended that they are by the American practice of remelting all the iron employed for cannon and keeping it for some time in fusion. This practice at one time went so far as three and even four remeltings, the iron being kept in the fluid state for three hours at each melting. In this way the tensile strength of iron, ranging from 5 tons to 6½ tons in the pig, has become 9 tons at the first casting, and after remaining in the melted state for two hours, 13 tons at the second casting, and 15½ tons per square inch at the third casting, the period of fusion at each melting being from one to three hours. The final strengths thus reached are very great, in one case reported by Major Wade, of the United States Ordnance Board, a tensile strength of 20½ tons per square inch of cast iron having been obtained. The American ton is generally 2000 lbs., but the strengths I have quoted are in tons of 2240 lbs. These great tensile strengths do not appear, however, to give a tough metal, using the term tough to express the product of the cohesion and extensibility of the iron. It was found that, in employing iron having an average tensile strength of 38,000 lbs., or 17 tons per square inch for 8-inch guns, they burst at the seventieth or eightieth fire, while 10-inch guns, made from iron having a strength of 37,000 lbs. per square inch, burst at the twentieth round. This was known in 1851, and in the following year, at the Tredegar Iron Works at Richmond, Virginia, where I was then engaged, and which was one of the leading foundries for supplying cannon to the United States government, a return was made to iron of a strength of 30,000 lbs., which, having more elasticity, as it was then thought, gave a really stronger gun. It has since been ascertained that the real fault with the stronger iron was that it contracted more in cooling, and as insufficient provision was made for equal contraction throughout the casting, the guns of strong iron were thus under great initial strain from their own shrinkage. This very strong gun iron contracts generally $\frac{3}{16}$ths of an inch per foot in casting. The driving-wheels of American locomotives are of cast iron, and when, in 1851, to secure greater strength against breakage, gun iron of a strong quality was experimentally used, it was found that the wheels broke worse than ever, as they were strained to a great

extent by their own shrinkage before they came out of the foundry. This gun iron is simply the better classes of iron mixed and melted in an air furnace, the cupola never being used for guns, as indeed it never ought to be used for any castings intended to have great strength, on account of the over-heating of portions of the metal and the direct action of whatever sulphur may be contained in the coke. In the Bessemer process, where the exclusion of sulphur is so important, the pig metal is for this reason melted in a reverbatory furnace, or air furnace, as it is sometimes called.

Now, as all the processes whereby cast iron is strengthened are processes whereby its proportion of contained carbon and silicium is diminished, some quicker and much cheaper mode of effecting this object is required than that by remelting or by partial puddling. This quicker and cheaper mode would be had by a partial application of Mr. Bessemer's treatment, that is, by blowing air through the iron for perhaps three or four or five minutes, instead of twenty. But, it will be asked, if you are to have the Bessemer apparatus at all, why not convert the iron at once into steel? There are several reasons why we should not. To make steel, a much higher quality of iron, and generally the addition of spiegeleisen, is necessary. As steel, the metal cannot be run into goods, but only into an ingot, which requires very heavy hammers to forge it, as well as machine tools of unusual strength to finish it after forging; the wear of the converter and other plant would be much greater for steel than for toughened iron. The waste of metal before the finished article, whatever it might be, could be produced, would be greater for steel than for cast iron. I have recommended this partial application of the Bessemer process, and I believe that when more attention comes to be given to strength in castings, this treatment will be adopted. The apparatus for carrying it out would be exceedingly simple, and would be worked with but little trouble, a blast being derived from the rotary blower already described.

But absolute strength in the iron of large castings is of little consequence unless they cool, after pouring, in such a manner as not to leave them subject to considerable internal strains. We know that the late Professor Hodgkinson found that with the iron he experimented upon the compressive strength was six times that in tension, and hence that the bottom flange of a cast iron girder should have six times the sectional area of the top flange. But very few, if any, engineers adopt such a proportion, as the casting would, in all probability, crack in cooling. Most of my audience have seen the cast iron bridge over which the London and North-Western Railway crosses the Regent's canal. The first girders for this bridge were cast at the Tinsley Park Works. The iron made there was very hard; and I have been told by my friend, Mr. Shanks, who was engaged there at the time, that it would chill to a depth of two inches. It was used, among other things, for making rollers to roll steel. The Regent's canal bridge drawing was sent down there, and they made the patterns and cast the girders. They broke through and through in cooling. Then

they altered the patterns; and by pulling off the sand from the thicker portions of the castings, so as to equalize the cooling, a number were cast with the loss of one out of every six. At last, six were sent up to London; and of these every one broke in a thunder storm. Other girders were then cast of different form. Castings, over-strained in cooling, are apt to break even under a moderate degree of vibration; and the late Mr. Rastrick, once of the Bridgenorth foundry, and afterwards engineer-in-chief of the London and Brighton Railway, once stated in evidence how a number of cast iron boilers he had made cracked open after a peal of thunder.

I have seen, and so, no doubt, have many others, a railway wheel cast in a chill, and which, on being taken from the mould immediately after pouring, broke in two within a quarter of an hour. And, if the experiment were made, there is not the least doubt that a heavy gun, pulled out of the sand as soon as the metal had set, and then finished, would burst at the first round. The outside would cool first, compressing the liquid iron within. This, cooling afterwards, would pull away from the iron already set around it—or, if it did not actually separate, the strain of contraction would be such that the gun would be ready to crack as soon as it was violently disturbed. An unannealed glass tumbler is as good a comparison as any. The old-fashioned playthings, Prince Rupert's drops, illustrate the same effect of internal strain due to unequal cooling, glass being particularly brittle in this respect, in consequence of its low conducting power, and from its having no ductility when cold.

To make a casting of great strength it is necessary that all parts cool alike or nearly so. In the case of guns cast solid, the core bored out is often found honey-combed by retarded cooling; and the metal forming the surface of the bore can be proved to be under considerable initial strain in consequence. Of course, guns were cast hollow many years ago; but not until 1847 was it proposed to cool the core, after casting, by means of water circulating in pipes within it. Captain Rodman, in that year, patented the mode by which all the larger American guns have been cast. Within the core are two water pipes, one inside the other, and like those in Mr. Field's boiler, known to so many in this society. Water flows down the inner pipe, which is open at both ends, and rises through the outer pipe, which is closed at the bottom. A perfect circulation of water is thus secured. In casting one of the 20-inch guns, February 11th, 1864, water was thus run through the core for twenty-six hours, at the rate of thirty American gallons per minute for the first hour, and sixty gallons per minute for each subsequent hour, equal to 341 tons of water in all. The iron was considered of too hard a quality to be further cooled by water, and for the next twelve days air was forced down the bore of the gun at the rate of 2000 cubic feet per minute. During the first hour after casting, the water flowing in at 36°, came out at 92°. During the second hour, with twice the quantity of water flowing through, it came out at 61°. In other cases, in casting 10-inch guns, as much as 700 tons of water have been run through the core, the water-cooling

occupying four days, or nearly 100 hours. In some of these cases, a fire was made at the bottom of the gun-pit, and continued for sixty hours, the outer iron casing of the gun-mould being kept at nearly a red heat for the whole time. It is by these means that all parts of the gun are cooled alike, or nearly so, and, with iron of a tensile strength of, say, 13 tons per square inch, that such great endurance has been attained in firing.

Nearly all the railway wheels in use on the American lines are of cast iron, chilled on the periphery. It is not merely that these wheels are cheap, but they are preferred to the wrought iron wheels as used on English railways. I am not now speaking of the engine driving wheels, but of the carriage and wagon wheels, of from 2 ft. 6 ins. to 3 ft. in diameter, although the size is very seldom greater than 2 ft. 9 ins. The cast iron wheels run until they are worn out, and they wear for a long time; whereas the wrought iron wheels require frequent turning, and, still worse, their flanges soon become worn so thin as to become unsafe, a fact due, perhaps, to the inferior condition of the American lines. It was, however, a long time before the American founders could produce chilled wheels which should be safe under all circumstances; and when it is remembered that they are now employed as the leading wheels of the heaviest express engines working on lines, of which, what we should call the ballast, is sometimes frozen as hard as a rock for two or three months in the year, and in a climate where the mercury is occasionally from 10° to 20° below zero, or 40° to 50° of frost, and when it is added that these wheels do not break oftener than wrought iron wheels on the best English lines, it must be added that they are as safe as anything can be. In this I am speaking from my own knowledge, extending over a period of ten years, during the whole of which time I was closely connected with the leading American locomotive factories and lines of railway. The founders had to obtain not merely strong iron, in respect of tensile strength, but an iron of considerable toughness, and, besides, an iron that would chill well. As a rule such iron is only obtained by careful mixing; and it must be sought by long and costly experiment. I do not doubt that iron for excellent chilled wheels, if they were ever required, might be found in England; but I would not run the risk of saying what mixtures would produce it, although I should say Blænavon cold blast and the Forest of Dean irons would enter into such a mixture, with a little iron like that made at Tinsley Park for hardening. The chief difficulty with the American founders was that presented by the unequal contraction of the wheels in cooling. At first the wheels were made with spokes, but as the rim was quickly cooled in the chill, thus compressing the still fluid iron in the nave, which subsequently contracted away from the rim, it was necessary to divide the nave radially into two or more portions, and to afterwards fill the openings thus made in the nave with lead and antimony, a pair of stout wrought iron rings being shrunk over the ends of the nave, to compress it properly upon the axle. But it happens in the case of spoke wheels cast in a chill, that, from the greater quantity of iron at the ends of the spokes,

the chill is softest there, so that the tread of the wheel wears into as many flat spots as there are spokes. This is one of several reasons why the disk form is to be preferred for chilled wheels, but there was the difficulty of providing against their unequal cooling. The disk being whole or undivided, the nave had to be left whole also; and so, unless the disk could yield laterally during cooling, or unless the whole wheel was cooled uniformly, a great strain would result in the disk and rim. So the disks were dished, or curved in cross-sections; indeed the variety of form to be found in the earlier chilled wheels of the disk pattern was something remarkable. At last, one of the leading founders, Mr. Whitney, determined to try the effect of equal cooling. He cast his wheels solid, as the others had done, but with a single and perfectly flat disk, stiffened by straight or radial ribs at the back. Such a wheel, pulled out of the flask when red-hot, and thrown out to cool in the open air, would crack open in a few minutes. Mr. Whitney, however, took his wheels from the flasks as soon as the iron had set, and lowered them at once by machinery into a deep pit made in brickwork, and which had previously been heated as hot as the wheel itself. The pit being filled with wheels placed one above the other, and separated by iron rings, was closed air-tight, and left with its contents to cool. The cooling occupies three days; and it is therefore so much slower than the progressive conduction of the heat from one part of the wheel to another, that all parts must cool absolutely alike. The result is that the wheels thus annealed may be so nearly cut open, by a turning tool in a lathe, as to leave but a thin film of iron connecting the boss and the rim, and yet, until struck with a hammer, the nearly separated portions do not come apart. The chill appears to take place at the moment when melted iron meets the iron-mould; and the heat of the annealing kilns does not affect the hardness of the chill in the least degree. Mr. Whitney's wheel factory in Philadelphia is the largest and best fitted in America; and his wheels, made and cooled as just described, are in use throughout the States; and are preferred to all others, even to the best English made wrought iron wheels, a number of which by the Lowmoor Company were put in use on the Hudson River Railroad in 1851, where the flanges of the tires soon came to cut so thin under the constant wriggling of the bogies or truck frames, that they had to be soon replaced with chilled wheels. Although we are considering the improvement of castings generally, I have dwelt at some length upon these wheels, because, from their severe service and the improvements made upon them, they illustrate in a convincing manner the importance of equal cooling. I wish it to be quite understood that I refer to chilled wheels only as an illustration, and however well they answer their purpose in America, I am not recommending their adoption here. But I am certainly of opinion that, in the case of many castings, especially those of irregular form and those of great size, their strength would be doubled were they properly cooled; and it is more from the want of precautions in cooling than from any inherent untrustworthiness in cast iron itself, that it has come to be regarded with doubt for purposes requiring great strength.

The next point to be considered is the treatment for making castings malleable. I should have said nothing of this were it not that, although exceedingly simple, it is but very little understood, for it is a very common notion that many and curious "chemicals" are required, and there is much mystery in the process. Making iron castings malleable was indeed among the lost arts, and old records show that it was lost and rediscovered more than once. The French philosopher Reaumur, who wrote upon it 140 years ago, observed that it was then practised as a great mystery in Paris. At last chemistry came to the aid of the metal worker, and he learned that what he had so long called sulphur in the iron—and sulphur was once a name applied to many substances—was really carbon, the same as charcoal or diamond. And chemistry showed how carbon would always forsake iron for oxygen, and that cast iron, treated with oxygen, was made malleable, as it always is, whether in the old refinery fire, in puddling, in pig boiling with forge scales and refinery cinder, in the Bessemer process, and in still other modes of treatment. In 1804, Samuel Lucas, of Sheffield, turned this knowledge practically to account. He took out his patent, too, and described his improvement very cleverly; and, to put it in the fewest words, it was nothing more than the present process of making castings malleable by roasting them, at a high heat, for from 72 to 120 hours in powdered hematite iron ore, or in any metallic oxide. The oxygen of the ore unites with the carbon in the iron casting, which, being thus left without carbon, becomes malleable—malleable, indeed, to a remarkable degree. It is commonly said that castings intended to be malleableized should be from very hard, brittle iron. It is not exactly because a casting is a brittle that it is of the best sort for the malleable iron treatment, but brittle castings contain less carbon than those from grey iron, and so the malleable process does not have to be so long continued to get rid of it. To those who are not accustomed to consider all forms of iron and steel as combinations merely of iron and carbon in different proportions, there is something a little paradoxical in the fact that a grey iron containing much carbon is tough; a white iron, containing less carbon, is brittle; steel, containing still less carbon, is also brittle; while wrought iron, containing but little carbon, is very tough. Even to a chemist these facts are not easy to be explained; nor shall I examine them further here, it being sufficient merely to have shown why a white and brittle cast iron, such as some of the Ulverston iron of which clock bells are made, is the best for the malleable iron process, because it contains less carbon than a grey iron. The castings must be packed perfectly air-tight in layers of ore, and shut up in cast iron boxes, of which the joint should be luted. The natural ore used for purifying gas at the various stations of the chartered gas works would, no doubt, answer very well for malleable castings, although it cannot be said whether Mr. Hill's oxide would do as well. The goods should be heated very gradually, twenty-four hours being occupied in getting up, and twenty-four hours more in letting down the heat, besides the two or three days at full heat. The heat should be very even over

all parts of the goods, and while the full heat is on it should be kept constant by careful firing and attention to the draft. The iron ore may possibly fuse upon the surface of the casting, thus covering it with lumps or warts; but this is the result of too high a heat, or access of air. Oxide of zinc, which is abundant in some parts of America—as near New York—is preferable to iron ore, but those who cannot obtain the former can get on very well with the latter. The agricutural implement makers have turned the properties of malleable cast iron to good account for the tines of their cultivators. At the large works of the Messrs. Howard, of Bedford, unusually large pieces are made malleable by roasting in hematite ore. McHaffie's malleable castings made in Glasgow—and for which it is generally supposed that there is a patent, although I believe there is none—are no doubt made in much the manner described, as also, no doubt, are Crowley's, of Sheffield, although different makers add various chemical substances, which may act in the same manner as the iron ore, and thus, to a certain extent, replace it, although it is doubtful if they greatly promote its real action. Wherever a shape can be easily made in wrought iron, this is probably cheaper than a malleable casting, and it is doubtful, therefore, whether the latter will ever be extensively used. It may be added that the tensile strength of malleable castings varies according to their size, and the depth to which the decarburization extends. If they were freed of their carbon all the way through, they would be converted into wrought iron, or, say "homogeneous metal," as the softest kind of steel has been called. So much of the casting, however, as is not decarbonized by the malleable iron treatment, remains cast iron, and has only the strength of cast iron. The effect of the process is generally visible for only a small depth below the surface, but small malleable iron castings have borne a tensile strain of 50,000 lbs. per square inch.

On the last point named in the earlier portion of this paper—the production of chilled castings—there is not very much to be said. It is for the founder to ascertain, from his practice and from such experiments as he is in the best position to make, which irons will chill, and which will not. Of those that will chill, it is important, if the chilled casting have to be put under great strain, that the chill be well blended with the softer iron, instead of their being a distinct line of demarcation. It may be that the best application for chilled castings will be that for chilled shot, which, at far less cost, comes nearest to steel. To cast shot in chills, with the best results, it may be found best to subject the iron, just after pouring, to a considerable steam pressure. By simple mechanical arrangements, easily devised, a pressure of 100 lbs. of steam per square inch, equal to a column of iron upwards of 30 feet high, could be turned instantly upon a casting just poured into a chill mould. The effect would be to secure greater density and uniformity in the casting, and to render it stronger for its purpose. It is well known that "head," or a high rising column of metal over the mould, is an important matter in making strong castings, and that, in some cases, as in casting sugar mill rolls, this head

or "gate" of metal is well churned by manual labor. There can be no doubt that steam pressure would answer the purpose still better, nor that the best mode of applying this pressure might be easily determined.

The very cheapest applications of iron are in its condition of cast iron. For some purposes, as for heavy ordnance, it is questionable whether cast iron is not really equal to wrought iron and steel. It is certain that comparatively little has been done in this country to improve the strength of large castings, and that, in some cases, wrought iron has been adopted, without sufficient attempts to meet the requirement with a much cheaper and more adaptable material. It cannot be argued that, in arched bridges like some of those now erected and in course of erection over the Thames, wrought iron is equal to cast iron in its resistance to compression. It is probable that absolutely better and cheaper structures could be put up in cast iron. It is to be hoped that the careless practices which formerly prevailed of casting large pieces on the foundry floor,and of paying little attention to uniform cooling, have not permanently deprived us of one of the best applications of one of the most important materials of construction.

For the Journal of the Franklin Institute.

Notes of Shipbuilding and the Construction of Machinery in New York and vicinity.

Continued from vol. xlv, page 382.

The Steamer Neptune.—Hull built by Van Deusen Brothers, New York. Machinery constructed by Henry Esler & Co., Brooklyn, L. I. In government service. Owners, United States Government. Original owners, Neptune Steamship Company.

Hull.—Length on deck, 218 feet. Breadth of beam, 35 feet 8 inches. Depth of hold, 12 feet 4 inches. Depth to spar-deck, 19 feet 10 inches. Draft of water, 13 feet. Frames, molded, 16 inches, sided, 8 to 10 inches, apart at centres, 24 inches. Four athwartship bulkheads. Rig, schooner. Tonnage, 1341 tons, O. M.

Engines.—Vertical direct. Diameter of cylinders, 44 inches. Length of stroke of piston, 3 feet.

Boilers.—Two, tubular, located in hold. Fire surface, 4·580 square feet. Grate surface, 144 square feet. No blower to furnace.

Propeller.—Hibsch's patent. Diameter, 12 feet. Pitch, 20 feet. Material, cast iron.

Remarks.—The floors of this vessel are filled in solid for 100 feet. The keel is of white oak, sided, 14 inches, molded 24 inches. Put together in two pieces, each 12 inches in thickness, with 4-inch coatings, and thoroughly fastened with galvanized iron bolts. The stern is of white oak, naturally carved, sided, 13 inches, and molded, 15 inches outside of rabbet. The floors are of white oak, double, sided 8 inches, well bolted together, and square forward. The side and centre keels are 14 by 14 inches, and fastened with yellow metal. The bottom planks are $3\frac{1}{2}$ inches thick, increasing near the wales to 4

inches. The deck planking is of thoroughly seasoned white pine, 3 inches thick and 6 inches wide, fastened with two 6-inch galvanized spikes in each beam, and two 5½-inch spikes in each carling. The cross timbers are of solid white oak and yellow pine, 10 inches thick, and of an even depth with the keelsons.

Her masts are 78 and 81 feet in length, and 24 and 34 inches in diameter.

The engine department of this vessel is well fitted in every respect, especial care being taken that all articles were of first quality.

The Steamers *Nereus*, *Glaucus*, *Proteus*, and *Galatea* are sister vessels to the *Neptune*, built at the same time, and are also owned by the U. S. Government.

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The Steamer Golden City.—Hull built by Wm. H. Webb, New York. Machinery constructed by Novelty Iron Works, New York. Superintendent of construction, Captain Francis Skiddy. Route of service, Panama to San Francisco. Owners, Pacific Mail Steamship Company.

Hull.—Length on deck, 340 feet. Breadth of beam, 45 feet. Depth of hold, 23 feet 6 inches. Depth to spar-deck, 31 feet. Draft of water, 17 feet. Frames, molded, 15 inches, sided, 18 inches, apart at centres, 36 inches. Four athwartship bulkheads. Rig, brig. Tonnage, 3336 tons, O. M.

Engines.—Vertical beam. Diameter of cylinder, 105 inches. Length of stroke of piston, 12 feet. Diameter of piston-rod, 11½ inches. Diameter of crank-pin journal, 14 inches. Length of do., 18 inches. Diameter of beam-centre journals, 15 inches. Length of do., 21 inches. Fitted with a Sewell's condenser, having 5500 brass tubes, 9 feet long, the condensing surface of which is 8000 square feet.

Boilers.—Martin's horizontal tubular, placed in a nest. Diameter of face, 20 feet 4 inches. Depth, 11 feet 6 inches. Height, 11 feet 6 inches. Diameter of smoke-pipe, 10 feet. Each boiler has five furnaces. Fire surface in each, 3·379 square feet. Grate surface, 120 square feet.

Water-wheels.—Diameter outside of buckets, 40 feet. Length of buckets, 18 feet. Width of do., 2 feet. Diameter of water-wheel shaft journal, 22 inches. Length of do., 30 inches.

REMARKS.—This noble vessel is built of white oak, hacmetac, &c., and square fastened with copper and treenails. Around her frames extend iron straps, diagonally, and double laid, 4½ by ⅞-inches. Every precaution that could be taken was resorted to in the construction of this steamer, that she should be a vessel of comfort and safety. Her model is almost faultless and she is very fast. Her interior is designed with great skill and care for the comfort of passengers and with a keen perception of the beautiful. Under her deck it is very roomy, and not cut up with band-box saloons, like most of our ocean steamships. Her upper and main saloons are very large, accommodating from 1500 to 2000 passengers.

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The Steamer James T. Brady.—Hull built by Thos. Stack, Brooklyn, L. I. Machinery constructed by Fulton Iron Works, New York. In Government service. Owners, Arthur Leary & others, New York.

Hull.—Length on deck, 213 feet. Breadth of beam, 30 feet. Depth of hold, 9

feet. Draft of water, 7 feet. Frames, molded, 12 inches, sided, 6 inches, apart at centres, 26, 28, and 30 inches. Rig, none. Tonnage, 585 tons, O. M.

Engines.—Vertical beam. Diameter of cylinder, 45 inches. Length of stroke of piston, 11 feet.

Boiler.—Tubular. Length, 24 feet. Width, 13 feet. Fire surface, 3000 square feet. Grate do., 86 square feet. No blowers to furnace.

Water-wheels.—Crooker's adjustible. Diameter, 27 feet 2 inches. Face, 8 feet. Dip, when loaded, 3 feet.

REMARKS.—This vessel is of white oak, &c., and copper fastened. Iron straps extend around her frame; they are $3\frac{1}{2}$ by $\frac{3}{8}$-inches. She is supplied with an independent steam, fire and bilge pump, bilge injection, and valves to all openings in her bottom. She has given satisfaction to those connected with her.

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The Steamer Ajax.—Hull built by C. & R. Poillon, Brooklyn, L. I. Machinery constructed by C. H. DeLamater, New York. Superintendent of construction, John Baird. Route of service, Pacific Ocean. Owners, Wakeman, Gookin & Dickinson, New York.

Hull.—Length on deck, 224 feet. Breadth of beam, 35 feet 8 inches. Depth of hold, 18 feet 6 inches. Number of decks, 3. Draft of water, 16 feet. Frames, molded, 14 inches, sided, 9 and 8 inches, apart at centres, 26 inches. Floors filled in solid under engines. Rig, brigantine. Tonnage, 1357, O. M., 1355, N. M.

Engines.—Horizontal. Diameter of cylinder, 54 inches. Length of stroke of piston, 4 feet 4 inches.

Boilers.—Two, return tubular. Located in hold. Each boiler has 224 tubes, 10 feet long by 3 inches diameter.

Propeller.—Of Baird's design. Diameter, 13 feet 6 inches. Material, cast iron.

REMARKS.—This ship was built with the greatest care, both as regards materials and workmanship, the materials being of white oak, hacmetac, and locust; diagonally braced with iron straps $4\frac{1}{4}$ by $\frac{5}{8}$-inches, laid double, extending from floor-heads to upper deck, connecting with longitudinal iron bands running from stem to stern. The deck-beams are of Georgia pine and Maryland oak; the ceiling in the wake of machinery, of Georgia pine; the bottom plank is of white oak; the water-ways of white pine, and the topsides are built in hull. The fastenings used in her construction are yellow metal, copper, iron, and locust treenails.

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*The Steamer Golden Rule.**—Hull built by Henry Steers, Greenpoint, L. I. Machinery constructed by Morgan Iron Works, New York. Route of service, New York to Aspinwall, C. A. Owners, M. O. Roberts & others.

Hull.—Length on deck, 310 feet. Breadth of beam, 44 feet. Depth of hold, 12 feet. Depth to spar-deck, 25 feet. Number of decks, 3. Draft of water, 14 feet. Frames, molded, 17 inches, sided, 15 inches, apart at centres, 32 inches. Four athwartship bulkheads. Rig, foretopsail schooner. Tonnage, 3080, O. M

Engine.—Vertical beam. Diameter of cylinder, 31 inches. Length of stroke of piston, 12 feet.

Boilers.—Two, flue. Located in hold, and use a blower.

Water-wheels.—Diameter, 30 feet. Material, iron.

REMARKS.—This is a very fine vessel, being built of the choicest white oak, hacmetac, &c., fastened in the securest and most durable

* Ran on a coral island in the Carribean Sea, May 30, 1865, and was lost.

manner, and fitted with all the conveniences and comforts a vessel of her class requires. Her bottom planks are of white oak, 4 or 5 inches thick, and her keelsons are of white oak and yellow pine. The *Golden Rule* has made several runs on the route of her service, giving satisfaction to owners, builders, and passengers.

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The Steamer Gen. Barnes.—Hull built by Lawrence & Foulk, Greenpoint, L. I. Machinery constructed by Morgan Iron Works, New York. Route of service, New York, Havana, and New Orleans. Owner, H. T. Livingston.

Hull.—Length on deck, 230 feet. Breadth of beam, 35 feet. Depth of hold, 18 feet 6 inches. Number of decks, 2. Draft of water, 11 feet. Two athwartship bulkheads. Frames, molded, 16 inches, sided, 9, 10, and 12 inches, apart at centres, 28 inches. Rig, foretopsail schooner. Tonnage, 1348 tons, O. M.

Engine.—Vertical beam. Diameter of cylinder, 60 inches. Length of stroke of piston, 10 feet.

Boilers.—Two, flued. Located in hold. Do not use blowers.

Water-wheels.—Diameter, 26 feet. Material, iron.

REMARKS.—This steamer is of white oak, chestnut, &c., and square fastened with copper and treenails. Around her frames, which are partly filled in solid, extend iron straps, 4 by $\frac{5}{8}$-inches, diagonally and double laid, increasing their strength. She is fitted with pumps, injections, bottom valves, &c., as vessels of her class are required to be. Her passenger accommodations are excellent, and in every respect this steamer ranks well.

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The Steamer City Point.—Hull built by Geo. Greenman & Co., Mystic, Connecticut. Machinery constructed by James Murphy & Co., New York. In Government service. Owners, James Murphy & Co. & others.

Hull.—Length on deck, 203 feet. Breadth of beam, 30 feet. Depth of hold, 9 feet 6 inches. Number of decks, 1. Draft of water, 7 feet. Frames, molded, $12\frac{1}{2}$ inches, sided, 6 inches, apart at centres, 26 inches. Rig, none. Tonnage, 555, O. M., 1110, N. M.

Engine.—Vertical beam. Diameter of cylinder, 45 inches. Length of stroke of piston, 11 feet.

Boiler.—One, tubular. Located in hold. No blowers to furnaces.

Water-wheels.—Diameter, 27 feet. Material, iron.

REMARKS.—This steamer is of white oak, chestnut, and cedar, and square fastened with copper and treenails. She is strapped with iron straps, $3\frac{1}{2}$ by $\frac{1}{2}$-inches., and her bottom is coppered. Her water-wheel guards extend fore and aft and are half sponsoned.

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The Steamer New York.—Hull built by Jeremiah Simonson, Greenpoint, L. I. Machinery constructed by Allaire Works, New York. Route of service, New York to Aspinwall. Owner, Commodore C. Vanderbilt.

Hull.—Length on deck, 300 feet. Breadth of beam, 42 feet. Depth of hold, 26 feet. Number of decks, 2, Draft of water, 15 feet. Frames, molded, 18 inches, sided, 10 inches, apart at centres, 30 inches. Rig, foretopsail schooner. Tonnage, 2551, O. M.

Engine.—Vertical beam. Diameter of cylinder, 90 inches. Length of stroke of piston, 12 feet.
Boilers.—Two, tubular. Located in hold. No blowers to furnaces.
Water-wheels.—Diameter, 25 feet. Material, iron.

REMARKS.—This steamer is of white oak, locust, &c., and is square fastened with copper and treenails. Her floors are filled in solid. Iron straps diagonally and double laid, 5 by $\frac{7}{8}$-inches, extend around her frame, and in other ways she is constructed in the most approved manner. Her bottom is coppered, and she is furnished with pumps, injections, and cocks to all openings.

The Steamer Shamrock, now the Gunboat Isnomia.—Hull built by Thomas Stack, Brooklyn, L. I. Machinery constructed by James Murphy & Co., New York. Original owners, Arthur Leary and others.

Hull.—Length on deck, 211 feet. Breadth of beam, 27 feet 6 inches. Depth of hold, 9 feet 6 inches. Number of deck, 1. Draft of water, 5 feet 6 inches. Frames, molded, 12 inches, sided, 6 inches, apart at centres, 26, 28, and 30 inches. No rig. No bulkheads. Tonnage, 585, O. M.
Engines.—Vertical beam. Diameter of cylinder, 45 inches. Length of stroke of piston, 11 feet.
Boiler.—One, tubular. Located in hold. No blowers to furnaces.
Water-wheels.—Diameter, 28 feet. Material, iron.

REMARKS.—This vessel is of white oak, chestnut, and hacmetac, and is square fastened with copper, iron, and treenails. She is strapped with iron straps, 3 by $\frac{7}{8}$-inches, and her bottom is coppered. She has knees under her main deck, and is considered a fine steamer. The speed shown by her in her trial-trip induced the Navy Department to purchase her, and fit her for blockading duty. E. M. B.

(To be Continued.)

For the Journal of the Franklin Institute.

Work and Vis-viva. By JOHN W. NYSTROM.

My "masked battery" opened upon Professor De Volson Wood, of the University of Michigan, appears to have had a greater effect than was anticipated, and I can well afford to slacken my fire, although unaware of my "vulnerable points," which, he says, "cannot stand a fierce assault." It is not necessary to reply to the greater part of Professor Wood's last article, lest the discussion degenerate into a useless squabble. I shall therefore confine myself to the important points, with a view to clear up the confusion which still pervades the questions of power and work, inasmuch as he yet seems to maintain the old stereotyped error that "power is the work done in a unit of time."

The number which expressed the work done in a unit of time, will be equal to the number which expresses the power in operation, but that does not prove the two quantities to be alike.

Six cubic feet and six square feet, although identical in number, do not prove that a cubic foot is a square foot, merely because their numbers are alike.

Professor Rankin and others also say that "power is the work done in one minute," which is substantially the same as saying that a square foot *one foot thick* is a cubic foot.

Professor Wood further remarks: "Again, he (Mr. Nystrom) says F V T is the expression for work. Now, if T = one second, minute, or hour, do we not have F V = *the work* which is done in a unit of time?" Here it is necessary to resort to the elementary, and inform Professor Wood that T does not disappear in the formula for work, merely because it equals one or the unit, for on his reasoning we may set F = 1, and the work will be = V T = S the space, which is equally absurd. It will first be necessary to explain the difference between addition and multiplication.

When a quantity is multiplied by an abstract number, it will not change the *nature* of that quantity, but the product will be the same as the sum of so many concreate quantities added together; but when a quantity is multiplied by another quantity, the product becomes a third quantity different from the two first.

Let two square feet, for example, be multiplied by the abstract number three, and the product will be six square feet, or the sum obtained by adding together three times two square feet, which will also be six square feet; but if two square feet be multiplied by a *thickness* of three linear feet, the product will be six cubic feet, which is radically a different quantity from two square feet, or from three linear feet, which constitute its elements.

Professor Wood, however, in his examples above quoted, confounds specific or concreate quantities, such as time and velocity, with abstract numbers.

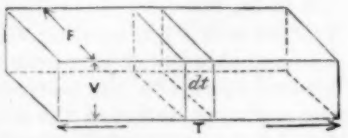
Power F V = F V × 1 the abstract number, and

Work F V T = F V × 1 minute, or whatever time or unit of time is a specific quantity.

Professor Wood quotes my statement that *power is the differential of work*, and says: "Do we not rightly infer from this that power is a part of work, an infinitessimal portion of it, and hence of the same kind as work?"

In answering this question it will be best to refer to a parallelopipedon, by which work has before been illustrated.

Let the accompanying cubic figure, F V T, represent the work, then the cross section F V represents the power, and F V *dt* the differential work. Now let us diminish *dt* until it becomes infinitely small, say = 0; then the solidity of the differential work F V *dt* = F V × 0 = 0, or there will be no solidity, or no work, whilst the quantity F V, which represents the power, is unchanged.



It may please Professor Wood better to say that "power is the differential coefficient of work."

I trust this will satisfy him that power is not the work done in a unit of time, and that the English unit for power is not a unit for work.

The popular expression "force of momentum" is perfectly correct. It does not mean that momentum is force, but that force is an element of momentum; same as we say, "the length of a rectangle" or "the surface of a solid." The momentum divided by time is the *force of momentum.*

It is to be regretted that in the conclusion of his article he "will pass over many important points," for the object of our discussion ought to be to reveal the subject, not to conceal it. I am, as Professor Wood has remarked, "a truth seeker," and think it unkind of him to "pass over important points."

The *Scientific American* says: "The main purpose of Mr. Nystrom seems to be to deny the position that work is independent of time, and he succeeds in involving the question in considerable confusion." After which, the editor of the *Scientific American* suggests to "free our minds from confusion" by taking "most important steps to use words always in their exact signification," *par example.* "Regarding work as the overcoming of physical resistance, it is plain that the aggregate amount of any given quantity is independent of the time required for its performance." Does not the *Scientific American* here convey the idea that *work is independent of what it requires,* namely, the time? The editor evidently means to say, that "a given quantity of work may be performed in any desired length of time," but he does not seem to conceive that the *work is dependent on whatever time required for its completion.*

On Aniline Black. By M. Lauth.

From the London Artizan, March, 1865.

Aniline black is a new colored derivative of aniline, which, so to say, completes the series of brilliant colors derived from this base. It differs, however, in many respects from the other colored derivatives. The mode of production, the way of fixing it on fabrics, and the insensibility to physical and chemical agents which it presents are points on which it differs essentially from the red, blue, and violet of aniline. Mr. Lightfoot's process, which the author quotes, is well known to our readers, and we shall only quote from this paper the author's new process for aniline black, which, it will be seen, and, indeed, is admitted to be, but a simple modification of Mr. Lightfoot's. Mr. Lauth's process consists in printing with the mixture of hydrochlorate of aniline and chloride of potassium an insoluble oxidizable salt, which will become soluble on the fabric—sulphide of copper, for example. By the oxidizing action of the chloric acid (or the chlorine which is set free by the reaction of hydrochlorate of aniline on chlorate of potas-

sium), the sulphide of copper is transferred into sulphate. In this same process, some of the disadvantages of Mr. Lightfoot's process are avoided. It is more economical, the mixture does not act on the steel rollers, nor does it weaken the fabric—not more, at all events, than madder black. The color is very permanent and is fixed at from 20° to 40° C. Its composition allows of its being printed with all sorts of colors. Aniline black has a specially beautiful appearance. It has a very rich black, velvety look. It is completely insoluble in water, alkaline, or acid, and is not affected by soap. Acids change the black to green, but the original color is restored by an alkali. Bichromate of potash deepens the shade, but a very strong solution slightly reddens it. Strong chloride of lime bleaches it, but the color returns after a time. M. Lauth promises another and further account of analine black in a short time.

FRANKLIN INSTITUTE.

Proceedings of the Stated Monthly Meeting, June 15th, 1865.

The meeting was called to order, with the President, Wm. H. Sellers, in the chair.

The minutes of the last meeting were read and adopted. The minutes of the Board of Managers were also reported, including the following resolution:

Resolved, That a book be prepared by the Secretary, in which any member of the Institute may enter the titles of such works as he deems desirable additons to the library, from which the library committee shall make such selections as they may deem expedient; and that the President be requested to call the attention of the members to the book at the next meeting of the Institute.

The following donations to the library were also reported: From the Royal Astronomical Society, the Institute of Actuaries, the Statistical Society, and the Society of Arts, London; the Natural History Society of Montreal, Canada; Prof. De Volson Wood, Ann Harbor, Michigan; Hon. Wm. D. Kelley, U. S. Congress, and Frederick Emmerick, Esq., Washington, D. C.; and from the American Philosophical Society, John F. Houston, Esq., Prof. John C. Cresson, Prof. John F. Frazer, Samuel S. White, Esq., the Schuylkill Navigation Company, B. H. Bartol, Esq., and the Board of Health, Philadelphia.

The minutes of the standing committees were then reported. The committee on weights, measures, and coinage was, on motion of Mr. Coleman Sellers, discharged. The committee on steam expansion reported progress.

The paper announced for the evening, by Theodore D. Rand, was then read as follows:

The Occurrence of Petroleum in Canada.

Petroleum is found in Canada in geological formations lower than

in any other region yet discovered. The lowest worked oil bearing stratum is the corniferous limestone of Enniskillen.

Geographical Position.—On an island near Great Manitoulin Island in Lake Huron a spring of petroleum flows from the Trenton formation. At Pakenham, C. W., the cavities of large orthoceratites in the same formation contain it in considerable quantity. The same rocks are found to contain oil at Cape Gaspé.

T. Sterry Hunt, *Journal of Science*, vol. xxxv., page 168, has described a very interesting development of petroleum in Canada which throws some light on the vexed question of the origin of the oil.

In a quarry of corniferous limestone in the township of Bertie, on the Niagara River opposite Buffalo, are seen massive beds slightly inclined, composed of a solid crystalline encrinal limestone, which appears destitute of petroleum, and owing to the presence of water impermeable to it. In some of these beds are large corals of the genus Heliophyllum, the pores of which are open but contain no oil. Two beds, however, one of three and one of eight inches, which are interstratified with these, are in great part made up of species of Heliophyllum and Favosites, the cells of which are full of petroleum. This is seen in freshly broken masses to be absent from the solid limestone which forms the matrix of the corals and resembles in texture the associated beds. As the fractured surfaces of the oil bearing beds become dry the petroleum spreads over them. A thin continuous bed of Favosites is met with, which is white, porous, and free from oil, though beds above and below are filled with it. The facts observed here appear to show that the petroleum, or the substance which has given rise to it, was deposited in the beds in which it is now found at the formation of the rock. We may suppose in these oil-bearing beds an accumulation of organic matters whose decomposition in the midst of a marine calcareous deposit has resulted in their complete transformation into petroleum which has found a lodgement in the cavities of the shells and corals immediately near. Its absence from the unfilled cells of corals in the adjacent and interstratified beds seems to forbid the idea of the introduction of the oil by distillation or infiltration.

Although petroleum has been found in these and many other less important localities over a wide area in Canada, there is but one county in which it has been sufficiently developed to make it of commercial importance, or to entitle it to the name of an oil region. This is Lambton County, C. W.

This county lies near the centre of the western part of the peninsula formed by Lakes Erie and Huron and the St. Clair River. The river Thames runs through this peninsula, following nearly the course of an anticlinal axis, stated by Logan to extend from the northwestern part of Lake Erie to the southwestern part of Lake Ontario. Wells have been recently put down along the Thames at Bothwell, in Zone township, with considerable success. The central and most important point, however, lies about 18 miles northwest of Bothwell at Oil Springs, in Enniskillen township. There wells have been sunken and immense quantities of oil obtained. The surface of this region, unlike that of

the Pennsylvania and West Virginia regions, is a perfect level, hollowed out to a depth of twenty to thirty feet by the largest streams, but without the slightest apparent undulation. A vast forest of large trees, oak, elm, beech, walnut, ash, hickory and basswood covers the soil everywhere. Six miles north of Oil Springs is Petrolia, where also several wells have been sunk.

The town of Oil Springs has sprung up in a very short time. It contains about one thousand inhabitants, several hotels, good stores, two churches, and a school house, besides refineries, blacksmith and cooper shops, &c. It is connected with Wyoming, a station on the Great Western Railway twelve miles north of Oil Springs, by a plank road, and by a similar road also with Sarnia, (on the St. Clair River opposite Port Huron, Michigan,) which is 18 miles northwest.

History.—Oil springs were known to exist in this vicinity at a very early period. There were chiefly three: one at Petrolia, one or more at Oil Springs, where in addition the dried up petroleum forms two "gum beds," as they are termed, of some acres in extent, and in the township of Mosa on the Thames.

These gum beds consist of a deposit from an inch to some feet in thickness, of a bitumen hard in winter, but becoming soft though not fluid in summer. It is generally mixed with vegetable matter, but sometimes is nearly pure.

In 1861 numerous wells were sunk, many through the surface clay only, others one or two hundred feet in the rock. Oil was everywhere obtained in fair quantity. During the winter of 1861–62, and the following spring, the great flowing wells which have made this region so famous were struck one after another. The yield from these was enormous, ranging by estimate from 1000 to 7000 barrels a day. This enormous supply brought down the price to ten cents a barrel at the wells, and of course rendered all the pumping wells worthless for the time being. The shipments of oil over the Great Western Railway for six months ending January 31, 1862, were 6246 barrels, while for the six months ending January 31, 1863, they were 57,550 barrels. In 1863 these wells ceased flowing and became filled with water.

The pumping wells had mostly been abandoned, and through careless tubing and neglect, had caved and ceased to yield oil when again examined. The machinery at all of them was of the rudest possible kind, constantly getting out of order.

In 1864 several companies were organized for petroleum mining in this district. They have gone to work in a thorough manner, with proper derricks and machinery, and soon will be in a position to test thoroughly the oil value of the region.

Geology.—The surface stratum of this region is a clay, probably of the drift period, containing fragments of limestone, and occasionally well preserved shells. This is from thirty to eighty feet in thickness. Through this the surface wells are sunk, which have yielded largely. The clay from a depth of sixteen feet near the gum beds contains oil in fissures. Under this throughout the whole region is the corniferous limestone. Between the two in Enniskillen and its vicinity, occur

shales of the Hamilton group, from 100 to 200 feet in thickness; and where these shales are absent and the limestones covered by the clay only, the rock, though impregnated with petroleum and pierced by springs yielding it, as at Oxford and Mosa, does not yield it in paying quantities. The shales seem to have served as barriers to prevent the exudation of the oil. The strata met with in boring are as follows:

Clay (with sometimes gravel),	30 feet to	80 feet.	Drift.
Shale (sometimes absent),	0 " "	100 "	Hamilton.
A soft clay shale (called soapstone),	60 " "	80 "	
Limestone,	3 ins. "	6 "	
Soft clay shale,	10 feet "	15 "	
Limestone,	15 " "	30 "	
Soft clay shale,	15 " "	30 "	
Limestone (not bored through),	350 " "	unknown.	Corniferous.

The softness of the shale gives rise to frequent cavings where wells are not properly tubed.

The Wells.—The following are the most important wells in this region. We give the local estimates of past yields:

Concession II. Lot 17, Enniskillen. Fairbank's Well. This yields about 60 barrels a week at the present time, and nearly all of it during the last three days of the week. None of the wells are pumped on Sunday. It is stated that when this well was pumped after a stoppage of about a month, hardly any oil was obtained for three weeks; the pump yielding abundance of water, with but a fraction of oil; and even now, after the stoppage over Sunday, the yield on Monday is almost all water; but the proportion of oil daily increases until on Saturday it sometimes reaches forty barrels, with comparatively little water.

Con. II. Lot 18. Shaw & Bradley Wells. These wells when first struck yielded by estimate 2000 barrels each per day. They were soon tubed, and the flow shut down to 400 or 500 barrels a day for about a year, when the flow ceased. The Shaw well flowed a full stream of pure oil from a pipe 2½ inches in diameter.

Con. I. Lot 18. Black & Madison Well. This is one of the most famous wells, and is frequently called the Bruce Well. It is 35 feet to rock, 237 feet to oil vein, and 27 feet below it. Nothing unusual was observed until the pumps had been worked for a short time, when suddenly the oil and gas burst forth, throwing the pump out of the well, which spouted oil like a fountain, 7 or 8 feet high, for 40 hours. Its supposed yield was 7000 barrels a day; and the ground is said to have been covered a foot deep with oil. Indeed the trees and stumps for some acres around it bear marks of the oil upon them with a regularity that nothing else could have produced. This well has been purchased by the Little Falls Company. Near it is a natural spring of oil, and two other wells, one of lubricating, the other of rock oil—such are here the distinctive designations.

On the same lot was the Phero well. This spouted up three or four feet from the mouth of the conductor, which was six inches square, and yielded some three thousand barrels a day for three or

four days, when it was shut off, and not opened for three or four months, when it failed to flow.

A surface well on this tract, sunk a few feet in the rock with crowbars, yielded by pumping with a spring-pole, 6000 barrels, at the rate of 30 or 40 barrels a day. There were in all 27 flowing wells, all of which were within a square mile. No wells except those at Petrolia were bored outside of an area about two miles square until recently.

While these wells were flowing, immense quantities of oil flowed down the creek and were lost. Several times it took fire on the creek, and blazed above the tops of the tallest trees. Evidence of this is even now to be seen in the track of the creek, marked by a border of lofty forest trees charred to their very summits, those further off being charred on the creek side only, and those a little further off uninjured.

At Petrolia, six miles north, is the only well in the region now flowing. It flows six or seven barrels a day, and has done so for three or four years quite steadily.

The present yield of the whole region is small. This is in great part due, as has been stated, to the abandonment of wells and unskilful pumping. Many of the wells were sunk by men of small capital, who, even if able to finish the well, were not able to erect proper engines and pumps. The machinery is, in almost all cases, very defective, and it is probable that the present engines, properly geared and with proper pumps would greatly increase the yield of oil.

The Oils.—The lubricating oil is of very good quality, commanding $12 per barrel in gold. The rock oil is heavy, containing little or no benzine, and has a peculiar and offensive odor. It is this odor which, without due care, creeps into the refined oil, that has given the Canada oil a bad reputation; but oil is now being produced that equals in all respects the best Pennsylvania. This odor seems to be due in part to a volatile sulphur compound. Some of the wells discharge sulphuretted hydrogen gas, and the same gas is given off during distillation. There are a number of small refineries both at Oil Springs and at the towns along the Great Western Railroad. The largest and best in the region is at Petrolia.

Paraffine.—We believe that there is yet to be in this region a great manufacture of paraffine. The crude oil contains very little benzine, the absence of which diminishes its value, but some 10 per cent. of paraffine can be obtained from it in the winter at little expense, and without injury to the other products. This manufacture, now attracting much attention in England, is comparatively new here, and has not been as successful as we think it must be in the future—not alone for the manufacture of candles, for which it is so admirably suited, but also for other purposes, in which its indestructible properties will make it in time almost invaluable. As a varnish for metal work exposed to the air or to corrosive vapors, it has no equal, for it is entirely unchanged by acids or alkalies, lengthened exposure to the air, or indeed by anything except high heat. Already a pa-

tent has been taken out for preparing wooden vessels to hold petroleum or benzine, by filling the pores of the wood with paraffine; and it is very probable that barrels lined with it might be used, with certain precautions, to contain acids, &c., in place of the present expensive and fragile glass carboys. The crude paraffine can be manufactured and delivered in Canada at 10 or 15 cents a pound, and afford a fair profit to the refiner. It is not difficult to purify, and there seems to be no good reason why it should not be thrown into the market purified, either in mass or as candles, at 20 or 30 cents a pound, instead of 50 to 75 cents, its present price, in which case it would soon supersede all other candles.

Point Gaspé.—There is another point in Canada, to which allusion has heretofore been made, which has recently attracted attention as a promising oil field. This is near Point Gaspé, on the Atlantic Ocean, at the mouth of the St. Lawrence.

Public attention was first drawn to this by the geological report of Sir Wm. E. Logan, published by government in 1863. At page 402, of this report, he says: "There is still to be described the Greenstone dyke, connected with the southern anticlinal at Tar Point. This dyke is of a dark grey color, weathering to a rusty red, and is traversed by numerous horizontal and vertical joints, and abounds in large and small druses. . . . . These cavities are filled with petroleum. This, in some instances, has hardened to the consistence of pitch. The peculiar odor of this substance, which has given the name of Tar Point to the locality, may be perceived at a distance of fifty yards.

Two petroleum springs occur along the line of this anticlinal. One of these is on the south side of the St. John's River, about half a mile above Douglastown. Here the oil oozes from the mud and shingle of the beach. The other is on a small branch of Silver creek, six or seven miles from Gaspé basin. The rock adjoining the dyke is a sandstone, but it is not improbable that here, as in Canada West, the source of the oil may be in the fossiliferous limestone beneath.

About a mile and a half south-east of Gaspé basin is found a layer of inspissated petroleum, resembling on a small scale the gum beds of Enniskillen, while to the eastward the soil is saturated with petroleum. Many other indications in the same neighborhood are enumerated.

The fossiliferous limestone spoken of belongs to the Lower Helderberg group, which lies at the summit of the Silurian rocks, and below the corniferous, the oil-bearing rock, of the Enniskillen region. It is about 2000 feet in thickness, and is frequently impregnated with petroleum, the surface of the country is mountainous, and deep valleys, both longitudinal and transverse, frequently occur.

No wells having yet been sunk in this region, it cannot yet be placed among the oil-producing districts; but the indications are certainly sufficient to warrant the sinking of a few wells to test the matter, for the very advantageous location of the region as regards the European market, and the abundance of wood for both barrels and fuel, would make a well of but small yield very profitable.

After the reading of this paper some questions were asked and answered as follows:

Prof. Rogers.—I would like to ask Mr. Rand whether there are any indications in this region of a material which might serve the purpose of asphalt. That which comes from Cuba has been used for a great variety of purposes, but has been restricted in its application by the expense of getting it; but in engineering operations it is an important and valuable material, and if it occurs in the oil regions in the West, it will be a source of great revenue to the people. I was not aware that it was found in this country till petroleum was discovered.

Mr. Rand.—My only personal knowledge of it has been in connexion with the gum beds of Canada West. This material is closely allied to asphalt, but whether it could be obtained pure from vegetable matter, I question. I would ask how the asphalt of Nova Scotia would compare with that of European or Cuban?

Prof. Rogers.—I have not seen the material itself, and dont know how it compares with that which is used in Europe, which is the Swiss asphalt, which occurs there in the limestone formations. It has been used in making roads, by breaking the rocks quite small, then heating it, and, while hot, laying it on the road-bed prepared with gravel, and rolling over the whole heated iron rollers; these rollers are heated by the roadside in furnaces provided for that purpose. It has been found that the material has been rendered sufficiently soft to adhere very well to the road. This mode of road-making is a great deal cheaper than the regular asphalt road, and much more durable, and can be repaired much more easily. In repairing, all they have to do is to place some more heated material where required, pass the redhot roller over it, and it forms a neat, durable road. Asphalt has been used for roads in France for many years, and in Paris, and the pavements in front of the Bourse, opera houses, and theatres are all of asphalt, which makes a very smooth road, curiously enough, not slippery. This article has also been used in covering the backs of arches to prevent the percolation of water and the formation of incrustations found on the interior of almost all the railway arches.

It has an extensive use in engineering, and it is desirable to have it accessible in large quantities in this country. The Cuban material is quite expensive, and that which comes from Switzerland must also be from the distance which it must travel to reach this country.

Mr. Rand.—I presume the largest quantities of that kind are found in California.

Mr. Chase.—What is the difference between the gum beds and the asphalt?

Mr. Rand.—The asphalt is a resinous substance, breaking with a clean fracture. The gum beds do not seem to have this pure resinous appearance, but are very much mixed with vegetable matter, so much so that it is not a sample of true asphalt. It is a mixture of the inspissated petroleum with vegetable fibres, twigs, grasses, and other matters, and seeming to have been a slow accumulation on the surface of the ground.

The thanks of the society were then tendered by the President to Mr Rand, after which was read in its order the

SECRETARY'S REPORT.

Civil and Mechanical Engineering.—We would call attention, in the first place, to several papers of great ability, which have appeared in certain journals, and which, though too extensive in their scope for a full notice in this place, are well worthy the examination and study of those among our members who may be interested in the subjects handled.

The first of these is a paper read before the London Institution of Civil Engineers, March 14, by Mr. J. W. Barzelgette, on "The new System of Drainage in London, the general Principle and History of Construction." (*Newton's London Journal of Arts*, vol. xxi, page 287.)

The second is a paper read before the same society by Daniel Miller, Esq., on "Structures in the Sea without Coffer-dams."

This essay treats chiefly of such structures when made of "beton" or concrete, *i.e.*, a mixture of hydraulic lime and broken stone or the like.

Among the remarkable applications of this material enumerated, we find the construction of the government docks at Toulon. In this case, great troughs, as large as the proposed docks, were formed of beton deposited in the sea and allowed there to harden. When the sides of these were finished above the water line, they were emptied by pumps, lined and finished within with stone, and provided with caissons at what were intended to be their entrances, after which the parts of the beton wall in front of these caissons were removed, leaving the docks complete.

Again, at Genoa, the mole was extended by the use of "beton," thrown into the sea from baskets, behind a light boarding to give it shape.

Yet again, at Algiers an immense breakwater was constructed of beton, in blocks of about 30 tons each, some formed "*in situ*" by filling wooden cases without bottoms, and removing the case when the interior material had set, and others made on land in similar cases and "launched" into the sea when finished. These blocks, after many years' exposure, show no signs of "wear," even at their angles and edges.

It is further stated that the Pont de l'Alma over the Seine, is built (arches as well as piers) of this material. (See *Civ. Eng. and Arch. Journal*, May, 1865, page 133.)

Lastly, we would call attention to the article on "The Treatment of Cast Iron in the Foundry," which will be found in full at another page of this *Journal.*

A bridge is proposed to carry the Great Western Direct Railroad across the Severn, which will be the largest bridge yet built. Headway, 122 feet; longest span, 600 feet, (150 feet more than the Menai bridge.)

As much as 40 tons of rust have been removed from the Menai and

Conway bridges, in cleaning their tubes. This does not speak well for their durability.

On account of unexpected difficulties, it is now computed that the Mount Cenis tunnel will occupy ten instead of five years in its execution.

Self-moving steam rollers are now used in Paris to consolidate the macademized roads, with a saving, it is stated, of 60 per cent. as compared with the ordinary rollers drawn by horses. The whole machine weighs 17 tons. This weight bears upon two cast iron rollers, so geared as to turn in a circle 45 feet in diameter.

There are now running in Paris 143 of Lenoir's gas engines. One of these is also in this city and will be exhibited before the Institute at the next meeting, (*i. e.*, in September.)

In a paper read before the London Society of Arts by F. A. Paget, on the "Wear and Tear of Steam Boilers," attention is directed to the fact that the shape of a boiler has a great influence upon its durability, in a sense not generally realized. Thus a boiler of an elliptical section will, under pressure, tend to assume a cylindrical form and settle back to its original shape on relief of the strain. The frequent repetition of this action will cause a deterioration of structure, and even a scaling off on the surface at the points of greatest tension. Such an action could not, of course, occur where the section of the boiler was circular. This and other facts mentioned in the essay above noticed, are worthy of attention. (See *Mechanics' Magazine*, 1865, page 261.)

Our attention has been directed to a machine for breaking hemp, invented by Joseph H. Siddall, of Shoemaker's Lane, Germantown.

This machine may be best described as an ordinary hand-breaker, so adjusted that steam or horse power may be applied to give it motion. By this means the excessive labor and exertion which renders hand breaking of hemp an objectionable occupation is avoided; one skilful workman can take the place of many, and the cultivation of this important staple (heretofore greatly discouraged by the difficulty of procuring hands to prepare the crop for market) will be promoted.

Physics.—Light.—In a paper read before the Royal Institute by Balfour Stewart, March 17, 1865, the prevailing ideas concerning the composition of the sun are fully discussed. It is worthy of note, that nearly all the conclusions now reached on this subject rest, upon the evidence which photography has enabled us to educe and to put on record in a permanent manner. The conclusions are briefly as follows:

1st. The existence of an atmosphere around the sun outside of its luminous envelop or photosphere. This is proved by the fact that photographs of the sun are less intense around the edges than in the middle, which is only to be explained on the supposition that an absorptive atmosphere surrounds the sun, causing more loss of power to the rays from the sides which must pierce it obliquely, and thus pass through a great depth, than to those from the centre which penetrate it by the direct and shortest road possible.

2d. That the "flames" or brilliant protuberances seen around the

edges of the moon in a total eclipse of the sun, belong to the central orb and not to the satellite. This was proved conclusively by a series of photographs taken during the eclipse of 1860 by De la Rue and others. In these the flames are shown in the successive pictures, to have suffered gradual occultation, and to have been gradually exposed in like manner by the moving planet, thus clearly being attached to or connected with the sun, and not in any wise related to the moon. These "flames," supposed to be in fact detached portions of the luminous envelop or extensions of the same into the solar atmosphere above mentioned, were also shown to possess remarkable actenic power, their shapes being more developed and better defined on the photograph than to the eye, and one *invisible* portion producing a distinct image on the sensitive film.

3d. That there are markings of a regular character over the solar disc, called, from their shape, willow leaves, ripples, &c. These are distinctly visible on some photographs by Mr. Nasmyth.

4th. That the spots in the sun are openings in its photosphere through which its relatively dark mass is seen.

This is fully demonstrated by the order in which the spot and its penumbra (the sloping sides of the opening) disappears as the luminary rotates. A series of photographs taken at the Kew observatory exhibit this in a clear manner.

Electricity.—Under this head we desire to draw attention to some plans for modification in the Bunsen battery, which were lately brought under our notice, and the results of certain experiments made in consequence.

In the first place, we here show you an apparatus constructed by T. & J. N. Chester, of New York, and presented by Mr. Fox, of Queen & Co., of this city. It is a medical coil, remarkable in the first place for its small size, but yet more for the peculiar arrangement of its battery. This consists of two little carbon cups one inch and a half in depth and the same in diameter, containing each a zinc cylinder about the size of an average thimble. For exciting liquid, water, containing a few grains of sulphate of mercury, is employed. With this the apparatus will run for several hours, giving a shock as severe as can well be endured. The apparatus is thoroughly efficient, and from its small size (measuring about 6 by 3½ by 2 inches) and its avoidance of acids, fumes, &c., very convenient. In the course of experiments made to test its efficiency, several facts were developed which we think worthy of notice.

Mr. Fox pointed out to us the circumstance that the addition of common salt increased the energy and constancy of this battery. A little reflection showed that in that case the sulphate of mercury and salt must change elements, so as to produce sulphate of soda (glauber-salt) and chloride of mercury (corrosive sublimate). These substances might therefore be substituted for those before mentioned, having the advantage that they can be obtained from any druggist, while the sulphate of mercury, can only be had at certain places, not being an article in general use. It was, moreover, found on experiment that

if a Bunsen cell was employed, in which the carbon element was of a porous character, (such, for example, as the common imported form manufactured by Deleuil,) the mercury salt might be dispensed with, and the battery (charged with a solution of glaubersalt only) would give for several hours a constant current, quite sufficient to operate a medical coil with all the energy desirable. In this case not only is all inconvenience from acids and fumes avoided, but we also get rid of the poisonous and expensive mercury salt, using one harmless and cheap in the extreme, (5 cents per pound.) The necessity of using *porous* carbon, arises from the fact that hydrogen is liberated in the action of the battery, which would collect on the surface of a dense carbon, so directly impairing the efficiency of the couple, or by occasioning a deposit of metallic zinc in its place, (after that substance had been dissolved in the fluid,) attaining the same end quite as effectually. The *porous carbon*, however, absorbs this hydrogen to a wonderful extent under these conditions, as has been proved by Daniell, Grove, and others, and thus keeps the couple in efficient action for some hours. The oxide of zinc formed, is dissolved by the solution of sulphate of soda, which *has* this power when in galvanic connexion, as was shown by Millon in 1645. See his paper, *Comptes Rendus*, T. 21, page 37.

We see, therefore, that a battery thoroughly efficient for medical purposes may be prepared by placing a cylinder of porous gas-coke within one of zinc, (which should come as near as convenient to it without touching,) and immersing both in a solution of glaubersalt. (A battery of this sort was here exhibited.)

We have also to show you another modification of this widely used Bunsen battery, from the same source as the preceding, *i.e.*, Chester & Co., of New York. The change here consists in the substitution of a solution of chromic acid, for the nitric acid usually employed in the above apparatus. This solution is sold under the name of electropoion fluid, and may be prepared by dissolving 5 ozs. of bichromate of potash in half a gallon of water, and adding to this 6 ozs, by measure, of oil of vitriol. In this case, part of the sulphuric acid combines with potash, setting free the chromic acid, which remains in solution.

As hydrogen, is liberated in the working of the battery, it takes oxygen from the chromic acid, forming water, and reducing the chromium to the condition of a sesquioxide, which is then taken up by another part of the sulphuric acid, and we have at last a solution of chrome alum or double sulphate of chromium and potassium.

We have found by experiment that this fluid works well in a battery which is not called upon for a large and continuous supply of force. Thus with the Ruhmkorff coil, where the contact is being continually made and broken, it gives results little if at all inferior to those obtained with the usual arrangement employing nitric acid. For the electric light, where there is a great resistance interposed, which materially cuts down the quantity, its working is very good; but where a full connexion of the circuit is maintained, as in electro-magnetic experiments, it runs down rapidly while in contact, recovering, however, when the circuit is opened for a few minutes. The reason of this is

obvious. The solution of chromic oxide, formed around the carbon by the action of the battery, is not decidedly different in density from the rest of the liquid; it is therefore sluggish in giving place to fresh liquid which is required to continue the action. Time must therefore be given for this circulation, or if this is denied, the force will rapidly decrease by the accumulation of this inactive material where an energetic one is demanded. For this reason it is that "carbons" of a porous character and large surface are desirable in this battery, the French giving better results than the harder (and otherwise much more desirable ones) manufactured in this country. For the same reason this solution will not act well in a Grove's battery, unless some mechanical means is employed to keep it in constant circulation. Such a battery, stirred by blowing air into it, was introduced some time since in France, but on the large scale cannot be conveniently applied.

Chemistry.—A new process for plating glass mirrors has lately been introduced by a M. Dode. Neutral chloride of platinum is dissolved in water, and oil of lavender is added, by which the platinum is separated in a state of fine division. Litharge and borate of lead are then added, and the mixture is painted over the surface of the glass, which is then heated to redness in an appropriate furnace. If this plan is practically successful, it would afford a material capable of useful applications in some optical instruments, where the double reflection incident to a glass plate "silvered" at the back is injurious; such, for example, as the kaleidoscope for the magic lantern, in which, otherwise, mirrors of the expensive and troublesome speculum metal must be employed.

M. de Chaubry presented to the Academy of Sciences, March 27, a note, describing a new solvent for aniline colors. This is simply a decoction of common soap-bark, (*quillāia saponaria*,) or the Egyptian soap-root, (*Gypsophila strutium.*) Among the advantages of this menstruum enumerated is the equality in tone obtained with mixed colors, which, in the ordinary solutions of mingled alcohol and water, changes as the proportions of these ingredients change, through the evaporation necessarily attending their treatment in use.

A paper on the utilization of brine from salted meat by application of dyalisis was read before the London Chemical Society by William Marcet, M.D., and will be found in the journal of that institution, Dec., 1864, page 405. From experiments made by this author it appears that the material obtained by the above means is very poor in nutritious matter, wanting the crystalloid constituents of flesh, such as phosphates, lactates, kreatine, and kreatinine. This fact should be remembered in connexion with the statements contained in papers quoted in this *Journal*, vol. xlviii, pages 22 and 143.

A new material is manufactured under the name of Linoleum, which is stated to possess many of the valuable qualities of india rubber. It is prepared by oxydizing linseed oil and then combining it with resins, &c. It is said to admit of vulcanizing.

An excellent and cheap ink may be prepared by any one after the following recipe:

Dissolve in about 4 gallons of hot water 3 ozs. of solid extract of logwood; to this add ½ oz. of bi-chromate of potash, dissolved likewise in a little hot water. As soon as the liquids are mingled they assume an intense purplish-blue color, and the ink thus prepared may be used at once. It acquires a black color on the paper while drying. It does not corrode steel pens. It does not fade, as we know by personal experienae during six years, for which time we have used it exclusively. The cost of materials is about 3 cents per gallon. It is often used to mark packages and boxes. Specimens of writing with this ink, six years old, were here exhibited, and bottles filled with it were presented to all the members present.

Metallurgy.—An improvement in the character of the product is said to result from the introduction of sulphate of iron and oxide of lead, in the ordinary iron puddling furnace. (*Mechanic's Magazine*, April 1865, page 216.)

The Academy of Sciences at Brussels have awarded a gold medal to M. Caron for an essay on steel. In the course of this paper occurs this statement: "Iron in becoming steel does not absorb nitrogen."

In our own *Journal* last year, vol. xlviii, page 283, will be found a very full description of a new form of iron furnace, known as the Rachette furnace. In the German *Miners' and Metallurgists' Journal*, published at Berlin, we find some account of one of these furnaces erected at Mülheim, from which great results were expected in the direction of economy of fuel and amount of product. As this is a matter of great practical interest, we insert here a translation of the article above mentioned, kindly prepared by R. H. Lamborn, Secretary of the American Iron and Steel Association.

Translated from the Berg und Huettenmaennische Zeitung, for Jan. 8, 1865.—Of the various advantages that have been hoped for from the Rachette furnace, viz: lower first cost, high daily production, and economy of fuel, only the first mentioned has been realized at the works at Mühlheim. The furnace cost only one-half to two-thirds as much as a common blast furnace. While many coke furnaces produce 60,000 lbs. of iron per 24 hours, the Rachette furnace produced only 30,000 to 35,000 lbs. of white cast iron in the same period. At Concordia furnace 0·37 lb. of coke is necessary to smelt 1 lb. of charge; at Mühlofen, 0·34 lb. of steel 0·28 lb., while the Rachette furnace requires 0·42 lb. coke to do the same work.

Without doubt the Rachette furnaces present eminent advantages in possessing a large hearth and an excellent distribution of the blast, but the common furnaces have made great advances towards excellence by widening their hearths and increasing the quantity of air thrown in.

Mr. Nystrom then presented several papers by Messrs. Antony Pamfilli and C. Latimer, which were referred to the Committee on Publications.

In reporting the proceedings of the Institute at the stated meeting, April 20, an error was made in describing the alloy prepared by the U. S. Composition Iron Co., New York. It is there stated to consist of zinc, *lead*, and tin, while it is in fact composed of zinc, *copper*, and tin.

HENRY MORTON, *Secretary.*